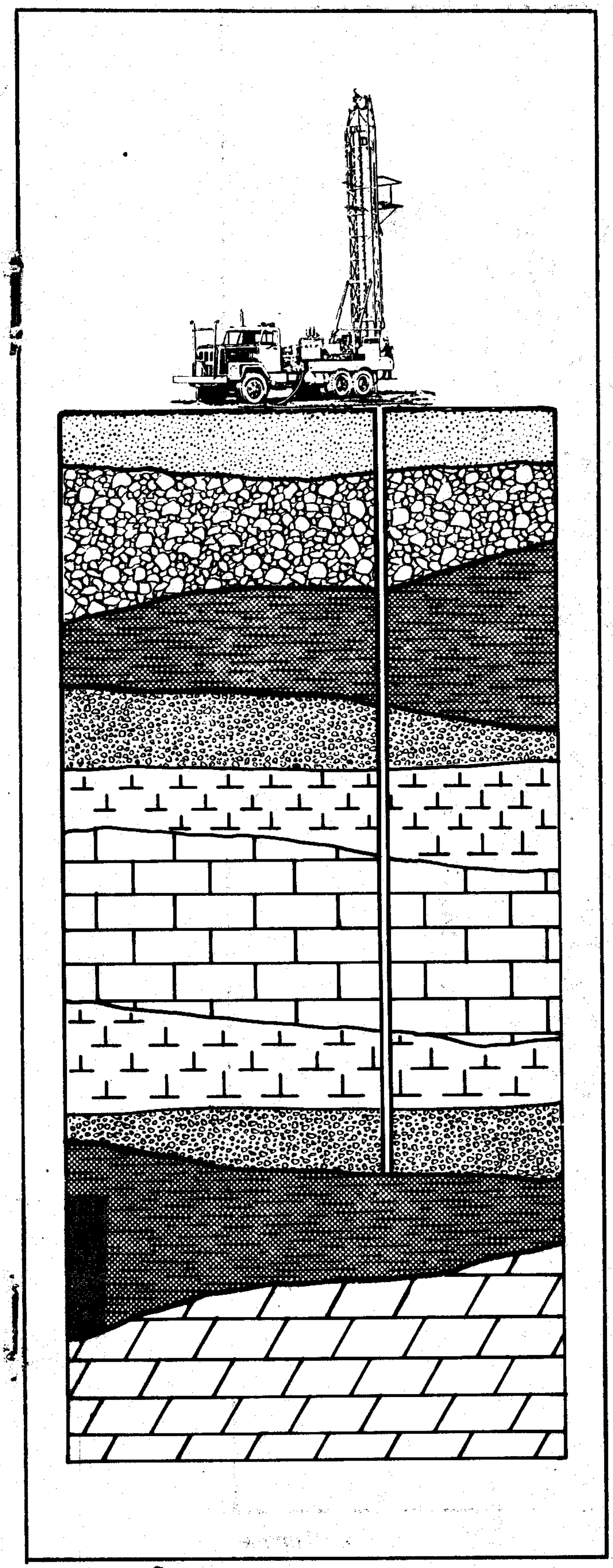

SHENANDOAH COUNTY GROUNDWATER

PRESENT CONDITIONS AND PROSPECTS

by

Kenneth R. Hinkle
and
R. McChesney Sterrett

VALLEY REGIONAL OFFICE

VIRGINIA STATE WATER CONTROL BOARD 1946

COMMONWEALTH OF VIRGINIA

STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT

Richmond, Virginia

Planning Bulletin 306

July 1977

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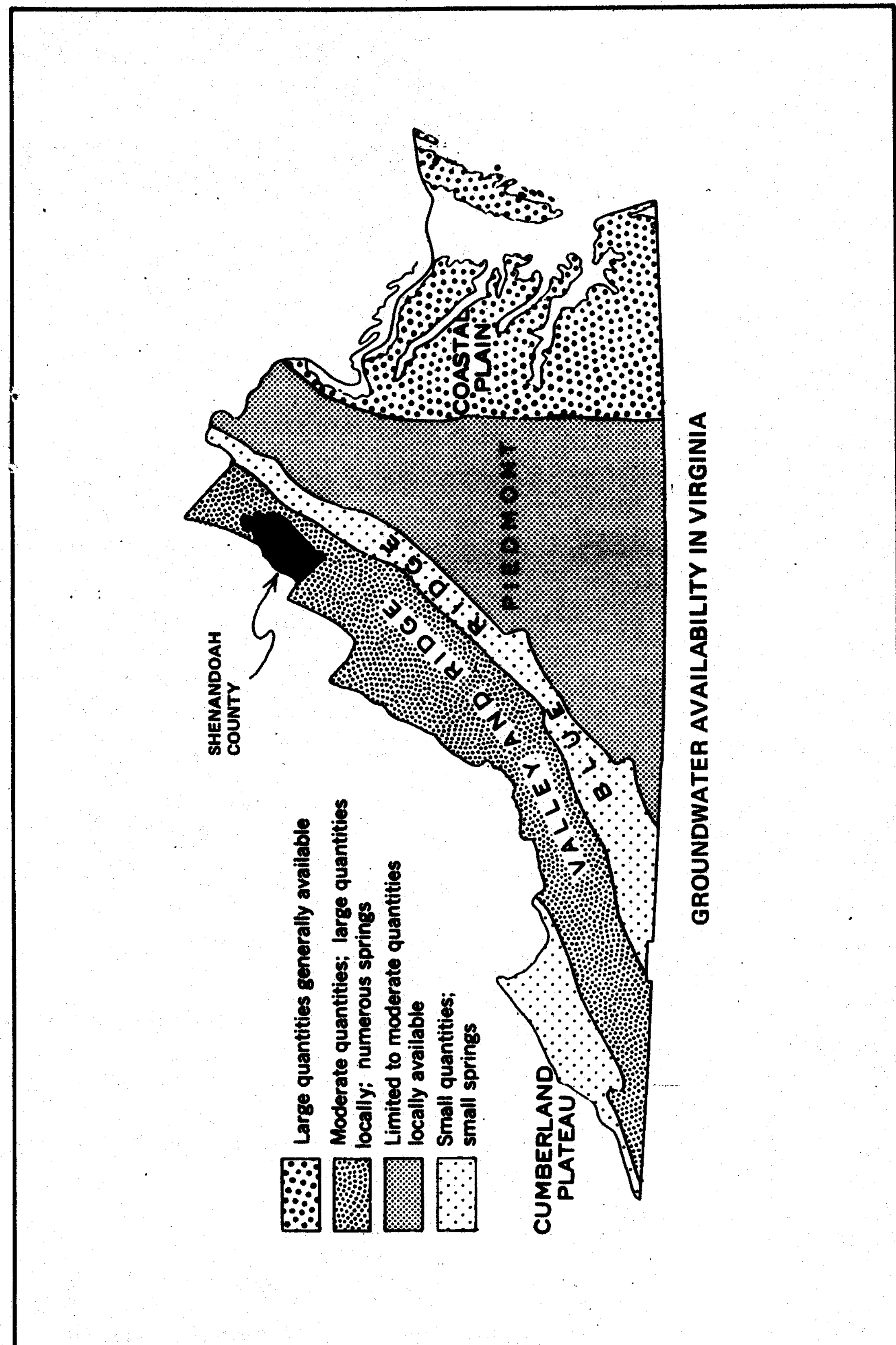

Source: Virginia State Water Control Board — BWCM

Frontispiece

GROUNDWATER OF SHENANDOAH COUNTY, VIRGINIA

By

Kenneth R. Hinkle

and

R. McChesney Sterrett

VALLEY REGIONAL OFFICE

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT

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ACKNOWLEDGEMENTS

Appreciation is extended to the citizens of Shenandoah County for permitting water samples to be collected from their wells and springs and for supplying much of the information contained in this report. Well drilling contractors who have been especially cooperative in supplying information include Burner Well Drilling, Dellinger Well Drilling, and Shenandoah Construction Company.

Quality data and selected pumpage data on public groundwater supplies were obtained from the Virginia Department of Health. The Soil Conservation Service provided maps and charts, and a portion of the hydrologic and climatic information was provided by the Virginia Water Resources Research Center at Virginia Polytechnic Institute and State University in Blacksburg.

FOREWORD

This report is one of a series intended to identify the groundwater resources of each county in the Commonwealth. The purpose is to provide all groundwater users, including private citizens, developers, investors, well drilling contractors, government officials, professionals and consultants, with a complete picture of the groundwater situation as it presently exists throughout Virginia.

Prospective groundwater users and anyone else interested in the development and protection of groundwater hopefully will gain insight into the opportunities and advantages inherent in this invaluable natural resource.

The State Water Control Board remains available for information, assistance and governmental action.

GROUNDWATER RESOURCES OF SHENANDOAH COUNTY, VIRGINIA

by

R. McChesney Sterrett

ABSTRACT

The groundwater resources of Shenandoah County offer a reliable source of high quality water for public, industrial and domestic use. Present groundwater development is minimal and is estimated to be in excess of three million gallons per day. The majority of the development has occurred in the Cambro-Ordovician carbonates, though these rocks are not necessarily the most productive. The younger Martinsburg shales have been developed to a lesser extent. The Silurian and Devonian shales and sandstones which comprise the Massanutten Range and the western portion of the County have seen very limited development.

It is estimated that present groundwater development can be tripled without adverse effects as long as responsible management practices are observed. Areas of maximum potential are areas where the Central Valley formations are overlain by alluvial and terrace deposits. Most notable is a stretch extending from New Market to Edinburg along the North Fork of the Shenandoah River and an expanded area along Stony Creek to the west of Edinburg. Formations in these areas include both the Martinsburg shale and various carbonate units.

Groundwater quality overall is very good. Exceptions to

very good quality do exist, however. Hardness and iron are found to be excessive in some sectors. Hardness is very high in the carbonate formations and somewhat less, though still "very hard", in the Martinsburg Formation. Iron concentrations are noticeably high in the Silurian and Devonian shale and sandstone formations but seldom are excessive in the carbonates and the Martinsburg Formation.

Groundwater problems are limited and infrequent but on occasion include well interference, sinkhole collapse, and local contamination caused by septic systems, agricultural runoff, and leaks and spills of petroleum products.

CHAPTER I

INTRODUCTION

Background

Shenandoah County is located in the northwest portion of the State (Plate 1), bounded on the west by West Virginia (Hardy County). Virginia counties forming the other boundaries are: Rockingham on the south, Page and Warren on the east, and Frederick on the north.

Formed from Frederick County in 1772, the County covers 407 square miles (324,480 acres). There are no independent cities, although there are six incorporated towns: Edinburg, Mt. Jackson, New Market, Strasburg, Toms Brook and Woodstock.

The population of Shenandoah County is 25,900, according to 1975 statistics furnished by Tayloe Murphy Institute at the University of Virginia. Projections by the Division of State Planning and Community Affairs for the year 2000 place the figure at 28,200.

Poultry is the prime source of revenue. In addition, livestock and dairy herds are increasingly important in Shenandoah County.

Present water supply is adequate, and there are no major surface- or groundwater-related problems known to exist in the County. Future water needs easily should be met through the abundant water resources present there. These resources, however, are not evenly distributed, and certain areas offer much greater groundwater potential than others due to the diversified topography and

and geology. No serious water quality problems affect the County, but the limestone terrains are conducive to groundwater pollution.

Purpose and Scope of Report

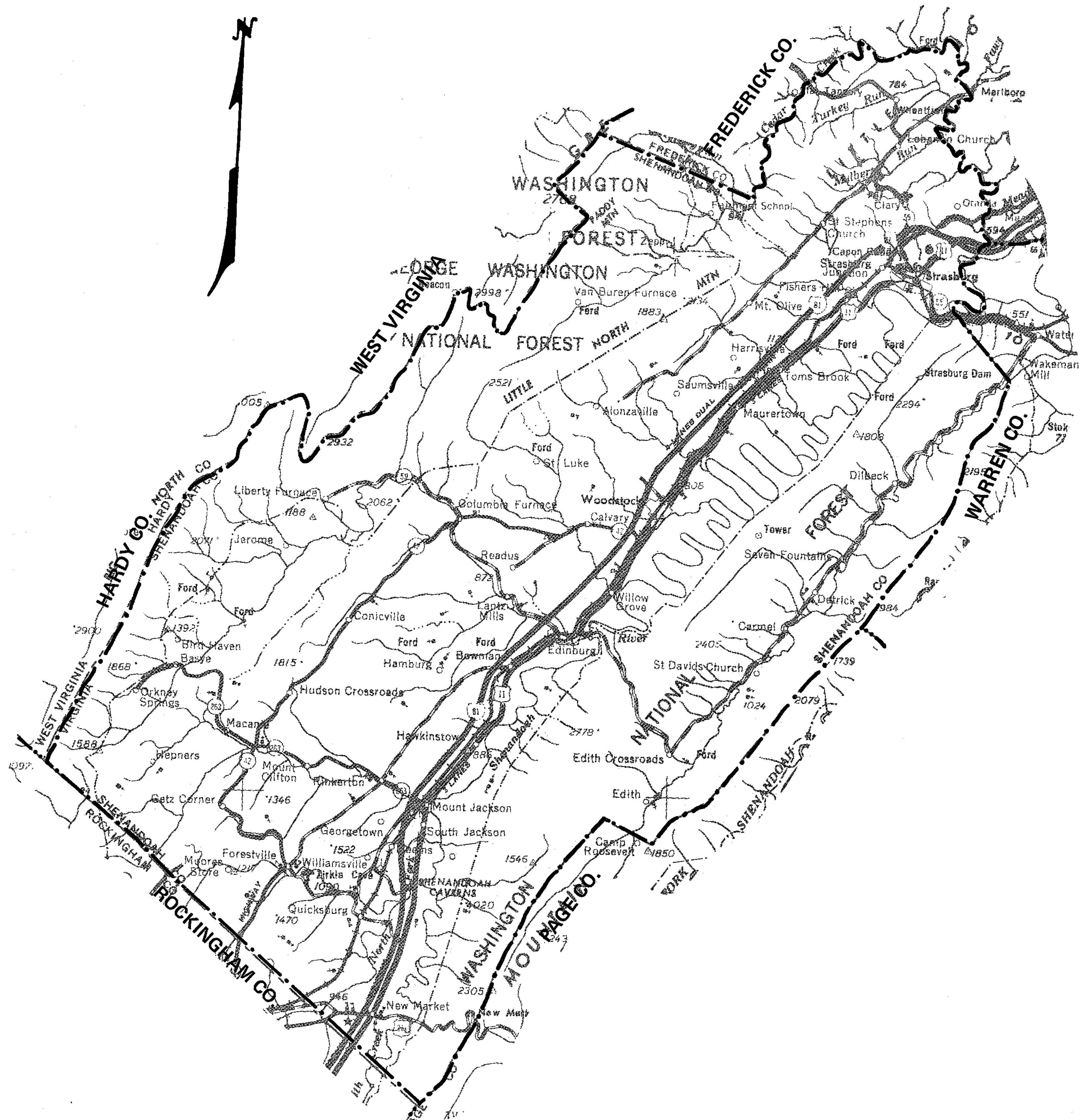
The principal goal of this report is to acquaint the public with groundwater conditions in Shenandoah County. In addition to providing some general information about the County, this report is a compilation of previous geologic and hydrologic investigations carried out under the auspices of the State Water Control Board and other state agencies. By discussing groundwater availability, development and quality, this report is intended to serve as a reference to local government, private citizens, developers, well drilling contractors, consultants, and anyone else desirous of information relative to utilizing and protecting the groundwater resources of Shenandoah County.

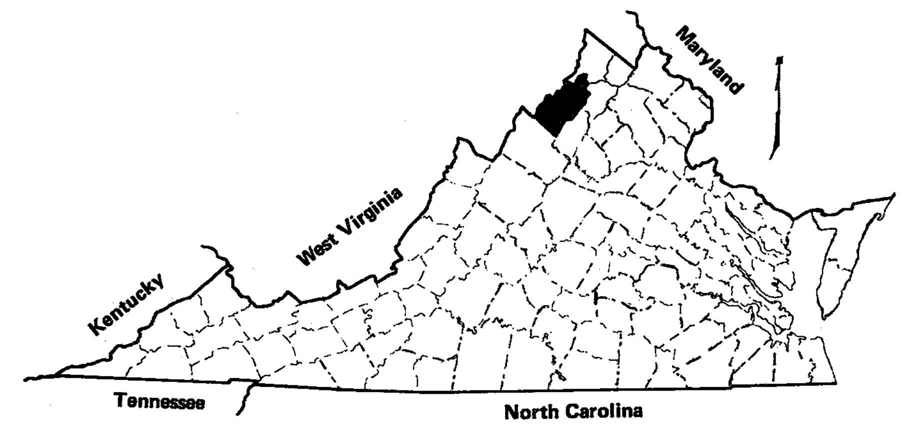
Methods of Investigation

Most of the general background and geologic information appearing in this report is a summary of previous work. Some of the information on water well construction, groundwater quality and groundwater withdrawal has been obtained from other state agencies, although the bulk of it has been collected by the State Water Control Board.

Much of the previously unpublished information on individual well construction data and quality analyses has been collected as a result of the Groundwater Act of 1973. This Act requires that a Water Well Completion Report (Form GW-2) must be submitted to

INDEX MAP OF SHENANDOAH COUNTY





POPULATION: 25,900 (1975)

AREA: SQUARE MILES: 507
ACRES: 324,480

SCALE 1:250,000

5 0 5 MILES

5 0 5 KILOMETERS

Source: U. S. Geological Survey; Virginia State Water Control Board — VRO

PLATE NO. 1

the Board for all wells drilled, and that owners of industrial and public water supplies submit quarterly reports (Form GW-6, Groundwater Pumpage and Use) detailing groundwater withdrawal. In addition, the Board requires that drill cutting samples be collected at 10-foot intervals on all public and industrial supply water wells and those wells which are drilled to unusual depths or are located in areas deemed deficient in geologic information.

A concentrated effort has been made over the past several months to gather information relating to quality trends in Shenandoah County. In addition to specific sampling areas, groundwater quality information is obtained from regular monthly sampling runs throughout northwestern Virginia. Domestic supplies are generally the sample targets, although some industrial supplies are checked occasionally. All of the public system quality information on file at the Board has been obtained from the Virginia Department of Health.

Another source of quality information is the Pollution Response Program (PReP), maintained by the Board for the sole purpose of responding to citizen complaints of water pollution of any type. This includes pollution of both groundwater and surface water by accidental or intentional spills of hazardous chemicals, oil, gasoline, refuse, and industrial wastes.

All well information, well completion reports and records of groundwater quality analyses cited in this report are on permanent file in the State Water Control Board Headquarters Office in Richmond and the Valley Regional Office in Bridgewater. These data are computerized for storage and retrieval and were used to compile Appendices B and C.

Previous Investigations

Two recent reports published by the Virginia Division of Mineral Resources offer comprehensive geologic information for about two-thirds of the County. A 1974 report by Robert S. Young and Eugene K. Rader entitled Geology of the Woodstock, Wolf Gap, Conicville, and Edinburg Quadrangles, Virginia (Report of Investigations 35, Virginia Division of Mineral Resources) and a 1976 report by Rader and Thomas H. Biggs entitled Geology of the Strasburg and Toms Brook Quadrangles, Virginia (Report of Investigations 45, Virginia Division of Mineral Resources) have been drawn upon heavily in preparing this report.

Groundwater reports of the area include works by R. C. Cady and R. H. DeKay. Cady's report, Ground-Water Resources of the Shenandoah Valley, Virginia (Bulletin 45 of the Virginia Geological Survey, 1936), is quite comprehensive and is the only major hydrologic report to incorporate virtually all of the County. In Development of Ground-Water Supplies in Shenandoah National Park, Virginia (Mineral Resources Report 10, Virginia Division of Mineral Resources, 1972), DeKay touches lightly upon some of the groundwater resources of the Blue Ridge region. Frank Reeves discussed another aspect of the subsurface water resource in his 1932 report, Thermal Springs of Virginia (Bulletin 36, Virginia Geological Survey). The Virginia Division of Water Resources report on the Potomac-Shenandoah River Basin (Volume I and III, 1968-69) included Shenandoah County, as did Trainer and Watkins' report on Geohydrologic Reconnaissance of the Upper Potomac River Basin (U. S. Geological Survey Water Supply Paper 2035), published in 1975.

Water Well Numbering System

Water Well Completion Reports are assigned a unique number by which the reported well is thereafter identified. Water quality and withdrawal information for that particular well are also identified by that number.

Each county in Virginia is assigned a three-digit county code, the code for Shenandoah County being 185. Within each county, wells are numbered sequentially and chronologically with a few exceptions. For example, a report received on a particular day might be numbered 185-16, while a report received the following day would become 185-17. All wells are assigned numbers as they are received and, therefore, appear at random throughout the summary. When citing specific wells in this report, the well number will be given without the county code.

When it is necessary to contact the Board about a particular well, it is advisable to refer to the owner (or location if more descriptive) and its well number. For example: New Market Battlefield, (185-98).

CHAPTER II

PHYSICAL SETTING

Physiography

Shenandoah County is situated within the Valley and Ridge Physiographic Province. This Province is characterized by alternating ridges and valleys trending in a northeast-southwest direction. The County is bounded on the east by Massanutten Mountain and on the west by Little North Mountain, while a narrow valley separates them. The lowest point in the County, just under 500 feet above sea level, is along the North Fork of the Shenandoah River where it flows into Warren County east of Strasburg (Plate 2). The highest elevation is approximately 3300 feet on Mill Mountain along the Virginia-West Virginia border.

The northern terminus of Massanutten Mountain at Strasburg is the most prominent landform. Rising to an elevation of 2,400 feet, the blunt peak can be seen for miles. Buck Hill, rising 600 feet above the valley floor northwest of Mt. Jackson, is one of the more notable landforms in the Central Valley, second only to the famous Seven Bends of the Shenandoah River located between Edinburg and Strasburg.

Caves and caverns are abundant in the County. In addition to the commercially-operated Shenandoah Caverns and Battlefield Crystal Caverns, approximately 80 other caves are known to exist. An abundance of sinkholes, almost exclusively found in limestone regions, indicates the area is riddled with subsurface solution channels and caves, a typical feature of karst terrains.

Drainage

Shenandoah County is located entirely within the Potomac-Shenandoah River Basin. Stretching from Highland County in the west to the Chesapeake Bay in the east, the Basin covers 5,706 square miles in Virginia alone and extends into West Virginia, Maryland, and Pennsylvania.

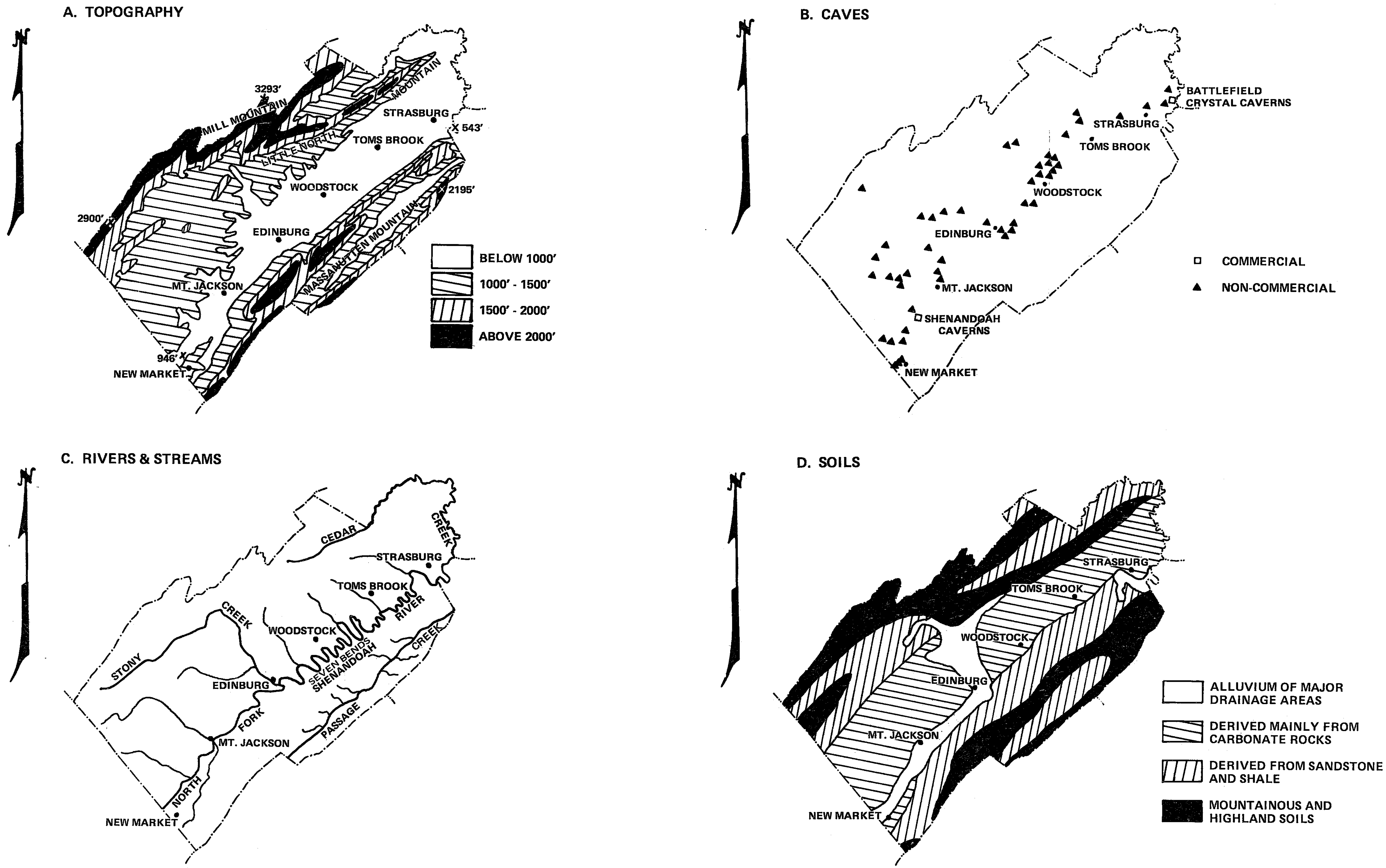
The North Fork of the Shenandoah River extends the length of the County and provides the principal surface drainage. Stony Creek and Cedar Creek are the two major tributaries and drain the southwest and northwest regions, respectively. Passage Creek, flowing through Fort Valley, provides drainage for the highlands of Massanutten Mountain.

Climate

The climate of the County is characterized by mild winters and warm, humid summers. The mountainous regions and the wide range in elevation are the two major factors controlling the climate.

The average annual atmospheric temperature for the County is 55°F. Extremes have been recorded as high as 105°F in July 1954 and as low as -10°F in January 1963. The average annual precipitation is approximately 34 inches; rainfall is the dominant precipitation factor. Summer rainfall is provided principally by showers and thunderstorms, the latter occurring on an average of 40 days. Although the average annual snowfall is around 25 inches, measurements in the last 43 years have varied from 2 inches to 65 inches.

PHYSICAL CHARACTERISTICS OF SHENANDOAH COUNTY



Source: Virginia State Water Control Board — VRO; Soil Conservation Service; Virginia Cave Survey

PLATE NO. 2

Table 1 lists temperature and precipitation data from the non-recording weather station at Woodstock maintained by the National Weather Service.

TABLE 1
1976 WEATHER DATA
RECORDED AT WOODSTOCK, VA

Month	Average Temperature (Degrees Fahrenheit)	Total Precipitation (Inches)
January	31.8	3.90
February	44.9	0.99
March	49.2	1.61
April	56.6	1.83
May	62.0	2.61
June	72.4	2.93
July	73.3	3.16
August	71.5	1.77
September	66.0	3.55
October	51.2	10.07
November	40.6	0.82
December	33.3	1.44
TOTAL	54.40	34.68

Source: National Oceanic and Atmospheric Association

Soils and Vegetation

Soil types can be grouped loosely into three major categories: mountainous; valley floor; and terrace and alluvial deposits. As indicated in Plate 2, better than half of the County is covered by mountainous soils. These soils are typically well to moderately-well drained and occur on ridges and steep slopes, and at the base of steep slopes in the form of colluvial materials.

Valley floor soils, which overlie limestone and shale uplands, are very rocky and usually well drained. Terrace and alluvial deposits, including flood plain material, roughly parallel the North

Fork of the Shenandoah River from the Rockingham County line to Edinburg and Stony Creek. These deposits, which are typically quite deep and well to moderately-well drained, are extremely important in the storage and transmission of groundwater. From Edinburg north to Strasburg, which includes the Seven Bends, alluvial-colluvial material does border the river but the hydrogeologically important terrace deposits are absent.

Vegetation is mainly of two types: forest lands and agricultural areas. The valley area is predominantly pasture and cropland, while close to 60 percent of Shenandoah County's 324,480 acres are forested. Approximately 35 percent of the forested area is included in the George Washington National Forest. Such major forest areas provide a shaded environment, relatively thick soil and dense undergrowth which retard surface runoff and erosion and encourage infiltration. These factors combine to make expansive woodlands an important factor in replenishing and maintaining both the groundwater and surface water resources.

CHAPTER III

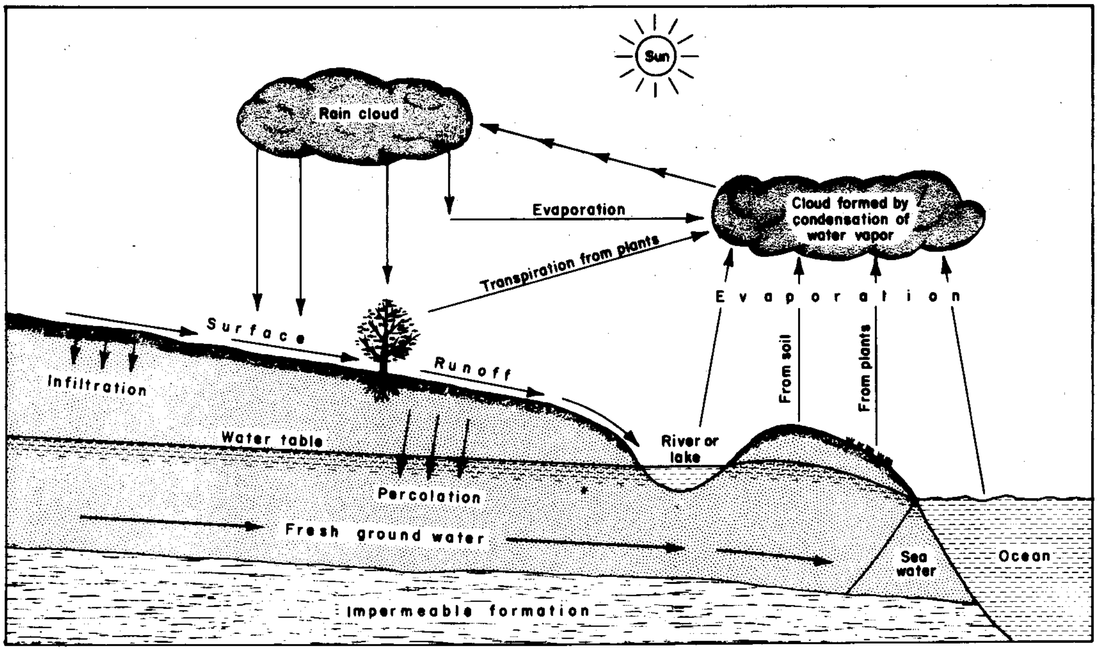
HYDROGEOLOGY

The Hydrologic Cycle

The close relationship between geology and the occurrence, distribution, availability and quality of groundwater makes geologic information a prerequisite to understanding the hydrogeology of an area. Topography, rock type and geologic structure are principal factors which govern the storage, transmission, yield, quality and utilization possibilities. Other elements influencing groundwater include soil, vegetation, temperature and certain works of man. Overriding most of these factors are quantity, intensity, frequency, duration and distribution of precipitation. The hydrologic cycle (Plate 3) explains the circulation of water among the oceans, air, land surface and underground.

Topography is a significant factor influencing groundwater conditions. As a general rule, low-lying areas near hills and mountainous regions should be considered as having greater groundwater potential than the higher elevations because runoff from slopes results in increased infiltration in valleys. Pervious soils, cultivated land and dense vegetation allow greater infiltration than do clayey and barren lands which are conducive to higher rates of runoff. High temperature coupled with a high degree of evaporation negatively affects groundwater recharge. In urban areas, runoff increases and infiltration diminishes due to the impermeable expanse created by paved areas and buildings.

The Hydrologic Cycle



Source: Gibson and Singer (1971) Plate No. 3

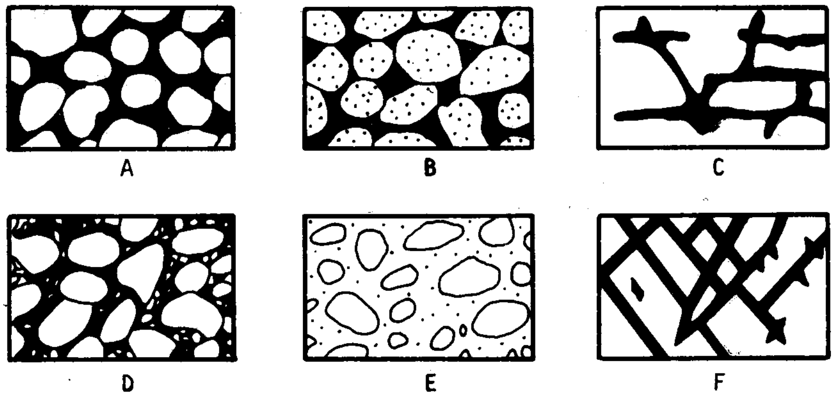
Geology and Groundwater

Different types of rock vary considerably in their ability to absorb, store, and yield water. Shenandoah County is underlain by sedimentary rocks which were deposited in ancient seas. These rocks contain water in voids, bedding planes, fractures and solution channels. The predominant rock types in the County are limestone, shale, sandstone, and unconsolidated sand and gravel. For the purpose of this report, limestone, a calcium carbonate, and dolomite, a calcium-magnesium carbonate, will be termed loosely as "carbonates".

Carbonate rocks have highly variable water-bearing properties and are poor to good aquifers. Where joints have been enlarged into solution channels by the dissolving action of water, large volumes of water may be stored and transmitted (Plates 4C and 4F). The solution action can produce openings as large as the greatest caves. Generally, it is believed that the formation of solution channels in carbonate rocks operates most actively above and immediately below the water table, where the water in the rocks contains a greater charge of carbon dioxide and circulates most vigorously. Carbonate rocks adjacent to major streams have a high potential for recharge and are relatively unaffected by seasonal water table fluctuations. Therefore, limestone and dolomite formations which outcrop near major streams may be very prolific aquifers, whereas those occurring in areas remote from major streams may produce only meager amounts of groundwater.

Shale has relatively high porosity, but permeability is very low. Poor to sometimes fair quantities of water may be obtained from pore spaces, joints, bedding planes and shaley partings, but shale generally forms an aquiclude, or barrier, confining groundwater to underlying aquifers. Clay has hydrologic properties similar to those of shale and is relatively impermeable; i.e., incapable of supplying water to wells.

Sandstone contains water in pore spaces which are dependent on sorting, grain size, shape, packing and, most importantly, degree of cementation (Plate 4E). Sandstone cemented with soluble calcite or unstable clay minerals may break down easily and develop high permeability. Some calcareous sandstone formations are excellent aquifers, but a sandstone cemented with silica may have practically no permeability unless fractured.



EXAMPLES OF ROCK POROSITY
(A) Well-sorted sediment - high porosity; (B) Well-sorted sediment consisting of porous pebbles - very high porosity; (C) Porosity resulting from dissolution; (D) Poorly-sorted sediment - low porosity; (E) Well-sorted sediment with intergranular space filled with "cement" - very low porosity; (F) Porosity developed along fractures.

Source: Meinzer (1923) PLATE NO. 4

Unconsolidated sand and gravel in alluvial and terrace deposits are highly porous and permeable and usually occupy areas favorable for groundwater recharge (Plates 4A, 4B and 4D). Sand and gravel beds lying adjacent to, and below the level of, a major stream often yield abundant supplies of groundwater, while sand and gravel in deep strata are also good aquifers. Similar deposits at higher elevations may contain little groundwater.

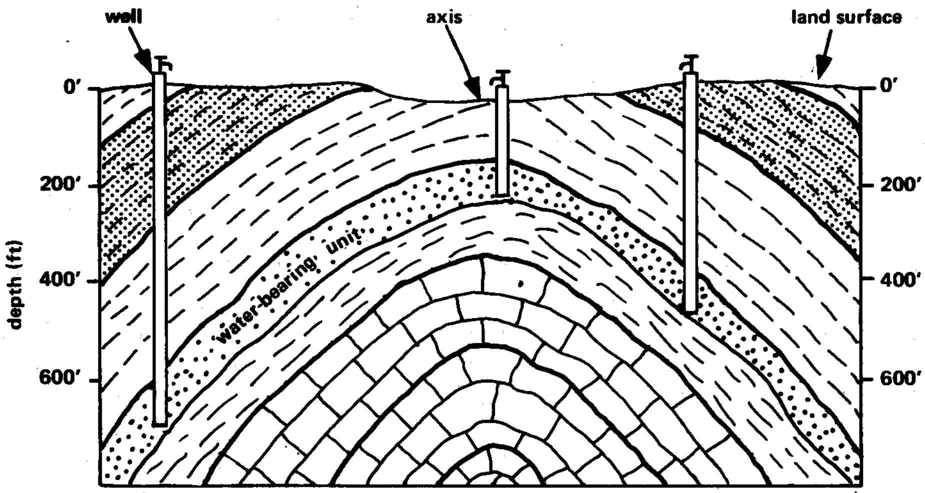
Igneous and metamorphic rocks have very low porosity and permeability. However, small supplies of water generally are available near the surface where weathering has partially decomposed the rocks. Below the weathered zone small quantities of water may occur in fractures and along contacts between different rock types.

Geologic structure may strongly influence the occurrence of groundwater, and this is especially true in certain areas of Shenandoah County. Anticlines (up-folds in the rock strata) may bring good water-bearing beds near the surface along their axes and bury them along the flanks (Plate 5A). Similarly, synclines (down-folds in rock beds) may bring water-bearing units near the surface on the flanks or may cause them to descend to great depths along the axis (Plate 5B). The axial portion of a syncline can act as a collection area and, if tapped, may yield significant quantities of water under high pressure. Water may flow under its own pressure to, or above, the land surface, and when this occurs, the well is termed "artesian". Similarly, excellent groundwater storage potential exists along well-fractured anticlinal axes, but water pressure is generally not sufficient to cause artesian conditions.

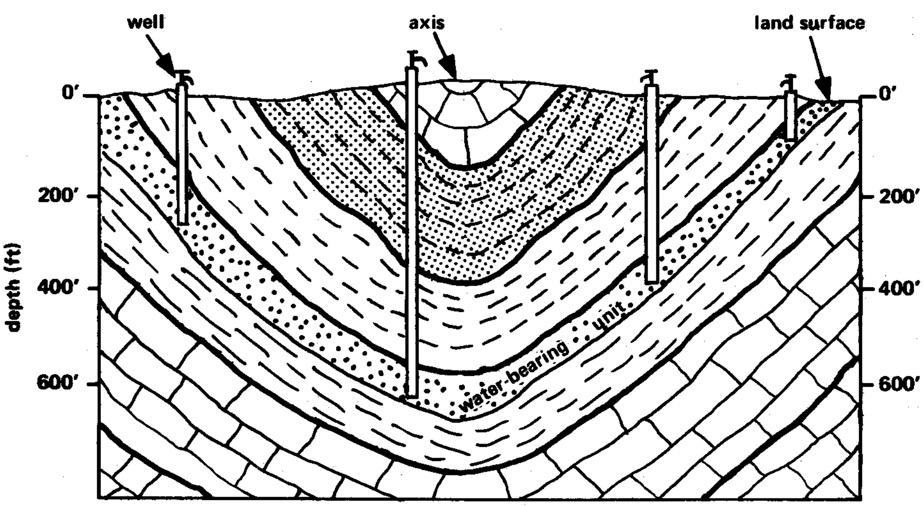
Faults are fracture zones along which there has been displacement of rock masses relative to one another, and they often parallel folding. The associated fracture openings in soluble rocks may be enlarged by the solution action of groundwater, thereby resulting in high well yields. Well yields from carbonate rocks are directly influenced by the size and number of fractures intersected (Plate 6). Faulting can also be detrimental to the groundwater potential of an area. Not only can it act as a collection zone for groundwater through its higher permeability, but it may also serve as a barrier to limit groundwater movement by causing the dislocation of a water-bearing formation.

Joints are fractures along which there has been no appreciable movement. They are favorable to groundwater occurrence, but, like

STRUCTURAL INFLUENCES IN GROUNDWATER AVAILABILITY



A. An anticline may bring a water-bearing rock bed near the surface at its axis or send it to great depths along its flanks.

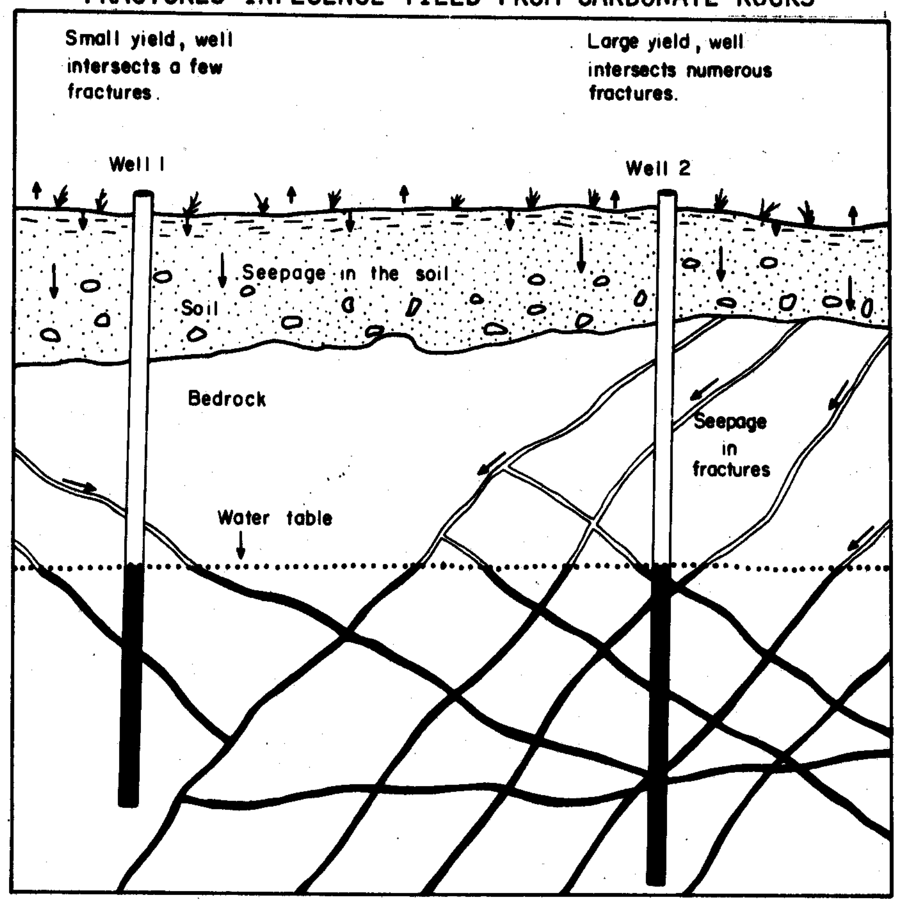


B. A syncline may bring a water-bearing rock bed near the surface at its flanks or bury it at its axis.

Source: Virginia State Water Control Board - VRO

PLATE NO. 5

FRACTURES INFLUENCE YIELD FROM CARBONATE ROCKS



Source: Newport (1971) PLATE NO. 6

faults and other fractures, tend to become fewer and smaller with depth.

Hydrogeology of Shenandoah County

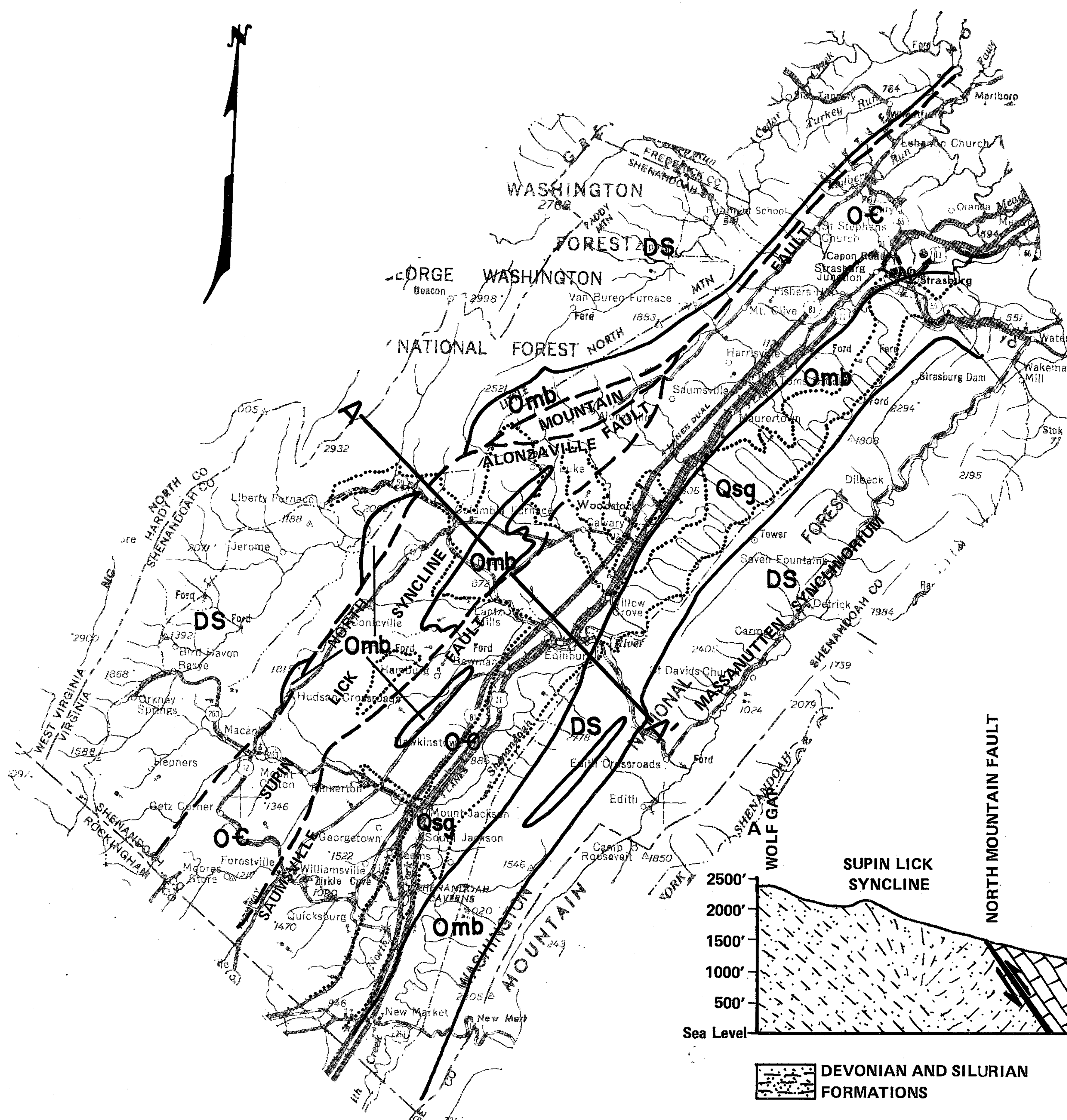
This County is composed entirely of sedimentary rocks occurring in relatively narrow northeast-southwest belts. These rocks have been heavily folded, and three major faults are present. Geologic and groundwater conditions of the area are illustrated in Plate 7.

Geologic Setting. The oldest rocks in Shenandoah County are those of Cambrian and Ordovician age (600-425 million years old). Exposed along the floor of the Shenandoah Valley, these limestone and dolomite formations were deposited when crustal downwarping caused a long, narrow trough to form in a northeast-southwest direction, generally coinciding with the present location of the Appalachian Mountain Range from Alabama to Newfoundland. This huge depression was invaded repeatedly by seas and served as a depositional site for thousands of feet of sediments over millions of years. During the Silurian, Devonian and Mississippian ages (425-300 million years ago) when uplift caused the sea to retreat, there was rapid erosion resulting in transport of clastic sediments into the depositional trough. These sediments later were consolidated into the younger shale and sandstone units predominating in Massanutten Mountain and from Little North Mountain west to the state line.

Following this long depositional and uplift period, the area was subjected to horizontal forces from the southeast which folded the rocks into a series of anticlines and synclines and, in some places, displaced huge masses of rock for thousands of feet along fault planes. Erosion and terrestrial deposition over the last 300 million years has altered the land surface to its present topography. The more resistant rocks, such as sandstone and quartzite, form the ridges while the less resistant shale and limestone units have been eroded to form the valleys.

The youngest deposits, less than two million years old, are the terraces and flood-plain alluvium which occur in proximity to the major streams. These materials have been deposited by the action of floods and consist mainly of sand and gravel.

HYDROGEOLOGIC MAP OF SHENANDOAH COUNTY



LEGEND

Qsg ALLUVIAL, TERRACE AND FLOOD PLAIN DEPOSITS
Chiefly gravel, some sand and clay. Good to excellent water-bearing properties depending upon thickness and lateral extent.

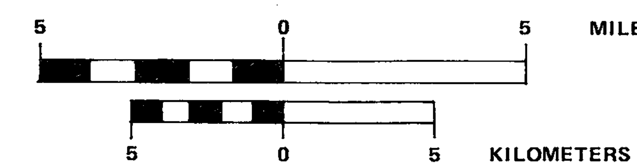
DS DEVONIAN AND SILURIAN FORMATIONS
Predominantly shale and sandstone. Poor to fair water producer for domestic supplies.

Omb MARTINSBURG FORMATION
Predominantly shale. Fair to good well yields, good to excellent when overlain by alluvial deposits.

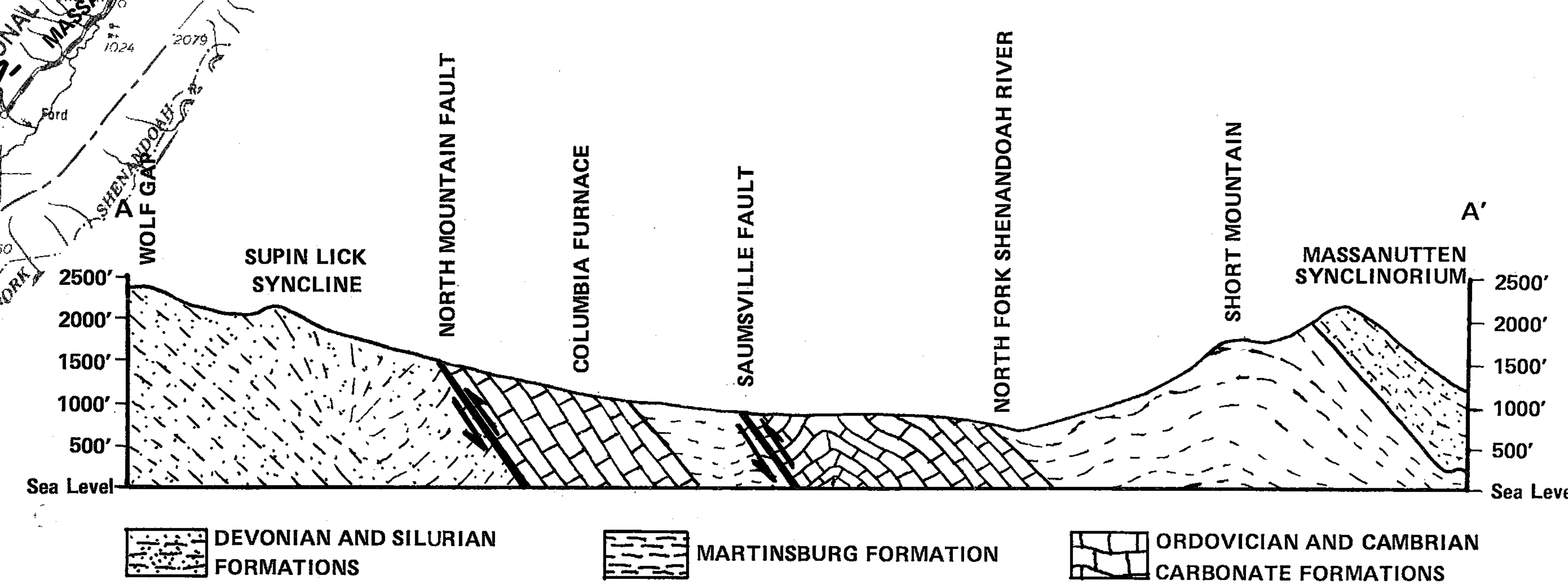
O-€ ORDOVICIAN AND CAMBRIAN CARBONATE FORMATIONS
Predominantly limestone and dolomite. Fair to good well yields for all supplies, good to excellent when overlain by alluvial deposits.

— — — FAULT

SCALE 1:250,000



SCHEMATIC CROSS SECTION



Source: Virginia State Water Control Board – VRO; Virginia Division of Mineral Resources

Geologic Formations and Groundwater Occurrence. The occurrence, lithology, and average thickness of the formations discussed above are detailed in the following paragraphs as a prelude to discussing groundwater occurrence and availability in Shenandoah County. Nomenclature is consistent with that used by Young and Rader (1974) and by Rader and Biggs (1976).

Groundwater conditions vary considerably across the County due to the diverse geology and topography. Carbonate formations are typically considered to be the best aquifers in the Valley and Ridge Province in Virginia, but the Ordovician-aged Martinsburg shale is considered to be the best groundwater producer in Shenandoah County. This unusual situation is explained in part by the presence of Smith's Creek and the North Fork of the Shenandoah River which traverse the formation throughout much of their courses in this County. The Cambro-Ordovician carbonates are very good producers, though not generally as prolific as the Martinsburg Formation. The Silurian and Devonian shale and sandstone units in Massanutten Mountain and the upland region west of, and including, Little North Mountain exhibit only poor to moderate potential for groundwater.

Cambrian units (600-500 million years old) consist of a thick series of dolomite and limestone with a few thin units of sandstone and shale. Two major and hydrogeologically significant belts of Conococheague outcrop through the County; Elbrook occurrences are few and very insignificant from a hydrogeologic standpoint, with the exception of those areas where alluvial and terrace deposits overlie the unit between Elkton and Grottoes.

The Ordovician-aged (500-425 million years old) Beekmantown, Edinburg, and Martinsburg Formations are the three principal units which, along with the Conococheague (Cambrian age), comprise the bulk of the central lowlands floor. In Shenandoah County, the Beekmantown is basically a dolomite unit but does contain major limestone zones; the Edinburg is a limestone, and the Martinsburg is a shale. The Martinsburg, with a thickness of possibly 3000 feet, is one of the most persistent formations in the Shenandoah Valley and occurs mainly in a three-mile belt extending the length of the County along the base of Massanutten Mountain. Rader and Biggs (1976) indicate limestone beds are present in the Martinsburg in the Massanutten Synclinorium.

The Silurian rocks (425-405 million years old) consist of a moderately-thick series of sandstones and shales. Silurian sandstone is highly resistant to weathering and is one of the principal ridge-formers in the Appalachian Mountains. It is these sandstone formations which support the Massanutten range and the ridges along the County's western border.

Devonian shales and sandstones (405-345 million years old) occur in three major areas within the County. Two extensive belts west of Little North Mountain and a large portion of Massanutten Mountain are represented by these units. Although they represent approximately one-third of the County's 507 square miles, they are very insignificant hydrogeologically.

Quaternary materials (2 million years old-present) represent the youngest deposits in the County. They are mainly flood-plain alluvium and terrace deposits above the flood plains that represent former levels of the major streams, notably the North Fork of the Shenandoah River. These deposits consist of gravel, sand, silt, and clay.

Geologic Structure. Of the many structural features present in Shenandoah County, two folded features and two faults appear to be primarily responsible for the overall structure of the area. Two major synclinal structures roughly follow the east and west borders of the County: The Massanutten Synclinorium and the Supin Lick Syncline, respectively. On the flanks of the Supin Lick Syncline sandstone and shale formations of Devonian age crop out west of Little North Mountain. The Massanutten Syncline is basically a very large trough which extends far beyond the County's northern and southern borders and includes Massanutten Mountain. This fold and its related minor structures are responsible for the wide expanse of Martinsburg shale present along the western base of Massanutten Mountain.

North Mountain Fault is the major zone of displacement and runs the length of the County. Older Cambrian carbonate units have been thrust over Ordovician, Silurian, and Devonian rocks, mostly shale and sandstone. Thick shattered zones are present where carbonate rocks have been involved in crushing due to fault activity, a phenomenon which greatly influences groundwater potential in the area.

The Saumsville Fault extends from a point approximately four miles due north of Woodstock to approximately the Rockingham County line in the southwest. Displacement involves the carbonate rocks along the valley floor and generally results in older carbonates being thrust over younger carbonates.

These structural features directly influence groundwater conditions. The Massanutten Synclinorium serves as a large runoff collection area to recharge the Martinsburg shale belt and the overlying alluvial materials along the west toe of the Massanutten Range. The Supin Lick Syncline performs the same function, though the units of which it is formed offer less potential for groundwater storage and movement. Extensive fracturing likely has occurred along the two major fault zones identified above, thus facilitating infiltration and groundwater occurrence.

Table 2 summarizes the major geologic units of Shenandoah County, including their water-bearing properties. Groundwater potential of the various geologic formations underlying the County will be elaborated upon in the next chapter.

Groundwater Movement and Storage

While there have been no detailed studies conducted of groundwater movement and storage in Shenandoah County, it is recognized that a very close relationship exists between surface water and groundwater. Groundwater movement and storage are influenced by topography, rock type, and geologic structure, and movement is generally in the same direction as surface runoff, only much slower. Movement and storage patterns are distinctly different in alluvial deposits, carbonate rocks, and shale/sandstone units.

TABLE 2

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES
SHENANDOAH COUNTY*

System	Age (Million Years)	Formation	Symbol	Character	Water-Bearing Properties
Quaternary	2-present	Alluvial and terrace deposits	Qsg	Sand, clay, gravel	Good to excellent, especially when underlain by carbonate rocks
Devonian	405-345	Hampshire	Dhs	Shale, sandstone	Poor
		Chemung	Dch	Shale, sandstone	Poor
		Brallier	Dbr	Shale, sandstone	Poor
		Mahantango	Dma	Shale, sandstone	Poor
		Marcellus	Dmr	Shale	Poor
		Needmore	Dn	Shale	Poor
		Ridgeley	Dri	Sandstone	Poor
Silurian	425-405	Tuscarora	Stu	Quartzite	Poor
		Massanutten	Sm	Sandstone, quartzite	Poor
Ordovician	500-425	Juniata	Oj	Sandstone, shale	Poor
		Oswego	Oos	Sandstone, shale	Poor

TABLE 2 (Continued)

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES
SHENANDOAH COUNTY*

System	Age (Million Years)	Formation	Symbol	Character	Water-Bearing Properties
Ordovician	500-425	Martinsburg	Omb	Shale; some sandstone, limestone	Fair to good; generally good along west toe of Massanutten Range
		Oranda	Ooe	Siltstone with limestone	Fair to good
		Edinburg	Ooe	Limestone	Fair to good
		Lincolnshire	Ol	Limestone, chert	Fair
		New Market	On	Limestone	Fair
		Beekmantown	Ob	Dolomite, chert	Fair to good
		Stonehenge	Ost	Limestone	Fair to good
Cambrian	600-500	Conococheague	Cco	Limestone, dolomite	Fair to good
		Elkbrook	Ce	Limestone, dolomite	Fair to good

*Modified after Young and Rader (1974) and Rader and Biggs (1976)

Source: Virginia Division of Mineral Resources;
Virginia State Water Control Board - VRO

Movement. Elevation is the prime factor determining groundwater movement in alluvial deposits. When the water table is at a higher elevation than a stream bed, groundwater will move toward the stream, thus maintaining surface flow during dry periods. During those times of year in late summer and early fall when the water table generally drops, conditions may reverse, resulting in seepage of water from the stream into the alluvium.

Groundwater movement within the thinly-covered carbonate rocks underlying the central portion of the County is more complex. Some of the carbonates are very dense and resistant to the dissolving action of water while others commonly contain countless fractures and solution cavities and provide for rapid movement and abundant storage of groundwater. The unpredictable size, shape, and direction of solution cavities makes groundwater movement very complicated in the carbonates. Where highly-fractured carbonates occur at or near the surface, optimal conditions exist for surface runoff and infiltration to enter into underground solution channels. Quite often a single sinkhole serves as a major infiltration point for groundwater recharge. Once water enters solution cavity systems, it behaves much in the same manner as surface streams and may discharge some distance away as a spring. Sometimes an entire stream may disappear in carbonate rocks and emerge as a large spring many miles away, thus giving rise to such names as Sinking Creek or Lost River. However, there are no known examples of this situation in Shenandoah County.

Groundwater movement in the shale/sandstone areas of the western part of the County and Massanutten Mountain is relatively simple. Water infiltrates the rock until it intersects bedding planes and then flows down-dip. Very few fractures are found in shale, so movement patterns are directly controlled by structure.

Storage. Maximum groundwater storage is possible in the alluvial and terrace deposits bordering major streams. These deposits consist mainly of non-cemented coarse sands, gravels and boulders which provide maximum voids. The most important groundwater storage area in this County is the alluvium bordering the North Fork of the Shenandoah River. Other notable examples are along Smith's Creek in the southeast and along Stony Creek from Jerome to Edinburg.

Where the flood-plain deposits overlie carbonate rocks with abundant solution cavities, groundwater conditions are considerably enhanced. Permeable flood-plain deposits minimize runoff and increase rates of infiltration. Not only do these deposits provide for storage at shallow depths, but deeper wells can often tap abundant supplies stored in the cavernous bedrock which will likely be saturated due to the water storage and transmission properties of the overlying material.

Storage capacity in carbonate rocks depends, as with movement, on the rocks' resistance to the dissolving action of water. Large solution voids sometimes act as reservoirs, and fractures resulting from structural activity can contain vast amounts of water.

Shale formations, as well as most sandstone units, seldom afford adequate groundwater storage. An exception in Shenandoah County, however, is the Martinsburg shale which covers one-third of the valley floor and outcrops along the large Massanutten Synclinorium. Four factors combine to make the Martinsburg a good groundwater producer in Shenandoah County: 1) high recharge potential from the western slopes of Massanutten Mountain; 2) extensive alluvial and terrace deposits overlying the formation along Smith's Creek and the North Fork of the Shenandoah River; 3) the synclinal (trough) structure; and 4) minor limestone beds and the highly calcareous nature of the shale.

Shale and sandstone units comprising Massanutten Mountain and the Little North Mountain sector are more typical and are considered relatively poor groundwater sources. Steep slopes and high runoff rates may render the beds unlikely to collect very great quantities of infiltered water, making them adequate only for the development of small-scale domestic supplies.

CHAPTER IV

GROUNDWATER POTENTIAL AND DEVELOPMENT

Groundwater Potential

The groundwater potential of an area is the ability of that area to yield groundwater. Potential is determined mainly by the geologic setting (rock type and structure) and topography. Geologic setting is the overriding factor in Shenandoah County. Once the geology has been determined, then topographic setting may be an important secondary consideration, especially in the highland areas in the east and west. Plate 8 illustrates the three major groundwater potential categories occurring in Shenandoah County. The map is based on the occurrence of geologic formations and their general water-bearing characteristics. The map is of a general nature, and exceptions will normally occur in each category.

Terrace and Alluvial Deposits. The terrace and alluvial deposits and the underlying carbonate and shale formations afford the greatest groundwater potential to be realized in Shenandoah County. The terraces are step-like and are formed mostly of sand and gravel deposited by the stream as it flowed at higher elevations in the past. The alluviual deposits are formed mostly of clay and silt and border practically every stream in the County.

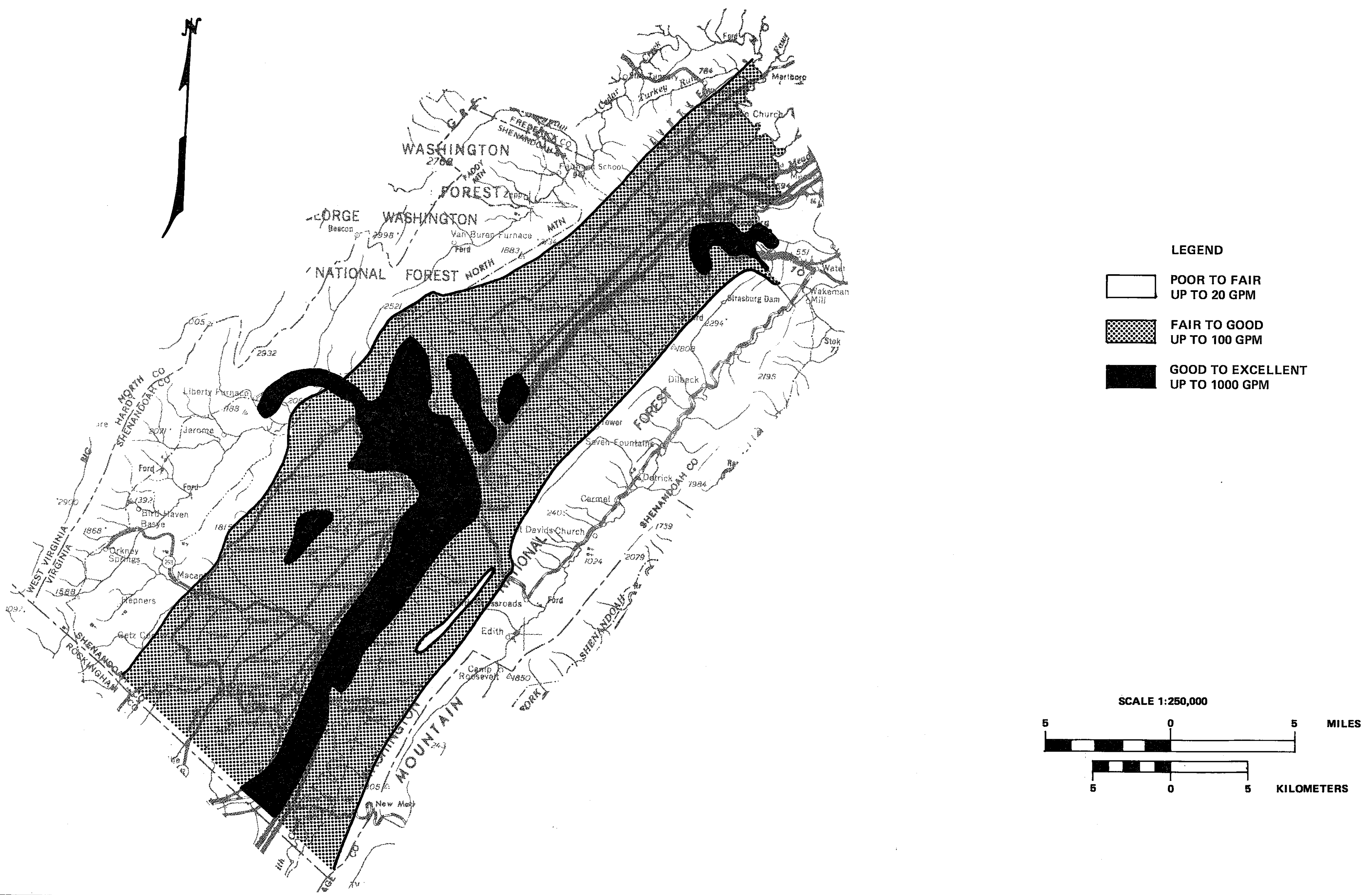
Young and Rader (1974) note that the ancestral North Fork of the Shenandoah River was responsible for the deposition of the terraces. They have identified three levels of terrace and indicate that the upper level alone is at least 160 feet thick and two miles in lateral extent. They are capable of storing and transmitting large quantities of water and act as a recharge mechanism for the underlying formations. Water table conditions are fairly uniform throughout the deposits, and excellent well yields may be developed at fairly shallow depths.

The bulk of terrace and alluvial deposits overlie the Conococheague, Beekmantown, Oranda and Edinburg carbonates and the Martinsburg shale. The most significant areas of terrace deposition include a belt extending from New Market to Edinburg and an expansive area fanning out along Stony Creek to the west from Edinburg. Several smaller terrace areas are located to the north and southwest of Edinburg. Minor alluvial deposits border the North Fork of the Shenandoah River extending from Edinburg north to Strasburg, and some terrace deposits are present at Strasburg.

Structural deformation in the form of the Saumsville Fault, a major fault zone, and alternating anticlines and synclines offer increased fractures and associated solution activity to enhance groundwater storage and transmission in the area west of Edinburg. Less severe deformation has occurred south of Edinburg; the Mt. Jackson Anticline is the most notable phenomenon.

<u>Cambro-Ordovician Formations</u>. The Cambro-Ordovician formations not influenced by terrace and alluvial deposits have far less potential than their counterparts. These rocks include both the carbonate formations and the Martinsburg formation, and although fair to good yields are generally available, topographic setting plays a

GROUNDWATER POTENTIAL IN SHENANDOAH COUNTY



Source: Virginia State Water Control Board — VRO

PLATE NO. 8

much more important role in determining the success of a well. Potential is more dependent on surface water recharge from higher elevations since there are no overyling saturated deposits.

The carbonate beds exhibit several major fault zones and assorted anticlines and synclines which offer extensive areas of fracturing. Potential generally increases with greater proximity to rivers and streams, since solution activity is accelerated and streams provide a source of recharge. Solution activity is widespread throughout all the carbonate beds as attested to by numerous caves and sinkholes.

The Martinsburg Formation appears to offer potential nearly equal to that of the carbonate formations. Though this is the exception rather than the rule, several factors combine to create this condition.

The largest and most prolific water-bearing exposure is located along the western toe of the Massanutten Range where it is traversed for much of its length by the North Fork of the Shenandoah River. The stream undoubtedly is an important recharge mechanism, and potential is further influenced by surface runoff from the steep western slopes of Massanutten Mountain. The Short Mountain Syncline, a large bowl-shaped structure just west of Massanutten Mountain, is occupied almost entirely by the Martinsburg Formation. The syncline acts as a large groundwater collection area which further enhances the groundwater potential.

Two minor western exposures of the Martinsburg also offer good groundwater potential though conditions are not conducive to the existence of the larger reserves commonly available from the exposure at the base of the Massanutten Range. Faulting in these areas, coupled with mountainous recharge areas, likely contribute to the potential of these exposures.

Silurian and Devonian Shale and Sandstone Formations. This series of formations comprises the Massanutten Range and the mountains in the western part of the County. Groundwater potential is not as great as that found in the other aquifer systems, yet the area has greater potential than is normally found in corresponding rock types of other areas. The rock units of the western mountainous area appear to offer higher groundwater potential than do the units comprising Massanutten Mountain. This is likely due to the extensive folding which has taken place west of the North Mountain Fault, whereas local deformation in the Massanutten Range proper appears to have been significantly less.

Groundwater Development

Groundwater is the principal source of water supply for Shenandoah County. The towns of Edinburg, Mt. Jackson, New Market and Toms Brook utilize groundwater wholly or in part for their water supplies. Only two towns, Woodstock and Strasburg, are supplied by surface water, and the back-up system for Strasburg is a groundwater source.

Projections based on population and housing statistics supplied by the Division of State Planning and Community Affairs (1972) indicate that approximately 49 percent of the County's population is served by groundwater. The remaining portion is supplied either by surface water or cisterns. Based on this percentage and on public and industrial pumpage information on file, total daily groundwater pumpage is estimated to be in excess of three million gallons per day (MGD). Industrial usage is somewhat less than 1 MGD, and public usage is approximately 1 MGD. Total domestic demand, including commercial and institutional users, is estimated to be approximately 1.5 MGD.

Groundwater development is confined mainly to the Central Valley area. Data on file indicates the three carbonate formations have been developed to the greatest extent. The Martinsburg Formation, though a very important water-bearing unit, has not been developed nearly as much as the carbonates. The Silurian and Devonian units have seen very limited development with the exception of the Bryce Mountain Resort area at Basye. Table 3 lists depth-yield relationships for the three aquifer systems. It is important to note that even though the table indicates the Silurian and Devonian units are very good groundwater producers, almost all the data available are from the Basye area which has to date proved to be an exceptional area considering the rock type.

Plate 9 shows groundwater development based on data currently on file. Though there are exceptions in each category, this presents a general picture of current development trends.

Public Systems. A public system is defined by the Virginia Department of Health (1974) as one which distributes water to more than 25 individuals or more than 15 connections. At present there

TABLE 3

AVERAGE YIELD (GPM) BY WELL DEPTH
FOR THE AQUIFER SYSTEMS OF SHENANDOAH COUNTY*

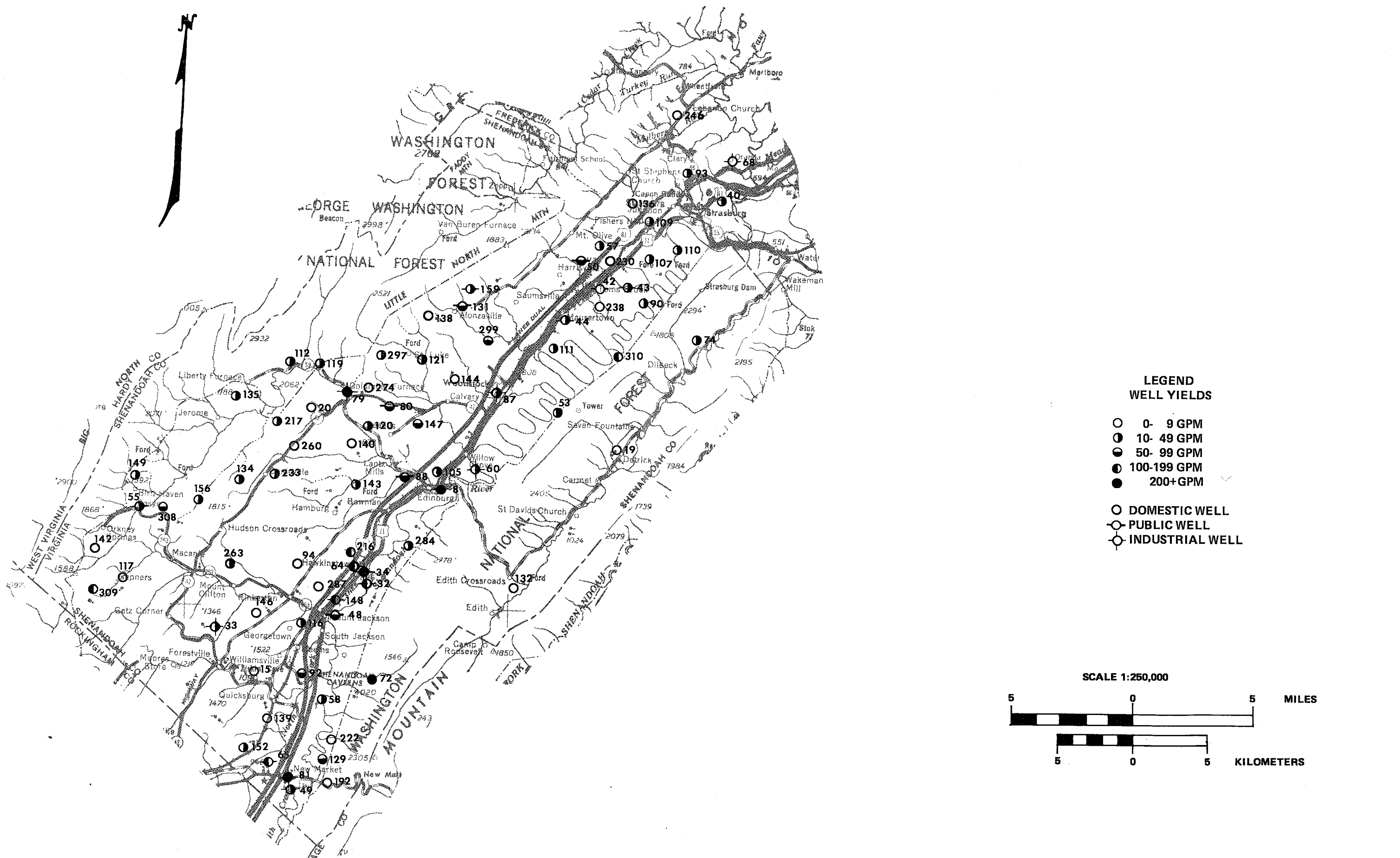
Aquifer	Depth (ft) 0-99	100-199	200-299	300-399	400-499	Below 500
Carbonate	(5)	(45)	(42)	(22)	(19)	(18)
Minimum	8	1	1	2	2	1
Maximum	20	220	160	205	400	100
Median	12	26	29	36	70	24
Martinsburg	(9)	(24)	(8)	(2)	(7)	(3)
Minimum	6	3	2	6	3	11
Maximum	50	183	275	31	200	450
Median	22	33	51	19	44	160
Silurian/ Devonian	(8)	(14)	(2)	(5)	(4)	(5)
Minimum	12	4	5	2	22	1
Maximum	60	80	20	90	38	7
Median	24	19	13	43	29	4

*All yields rounded to nearest gpm; parentheses () indicate number of wells used in making calculation
Source: Virginia State Water Control Board - VRO

are 31 public systems in Shenandoah County supplied by groundwater. Table 4 lists public users for which information is available. (Note: Table 4 does not include public systems supplying industries. These systems are included in the section covering industrial systems).

The majority of these public systems have been developed in the Central Valley area. A few of the systems, most notably the Stoney Creek Utilities Corporation which serves the Bryce Mountain Resort area, have been developed in the Silurian/Devonian shale and sandstone formations. Available well data for most public systems is incomplete.

GROUNDWATER DEVELOPMENT IN SHENANDOAH COUNTY



Source: Virginia State Water Control Board – VRO

TABLE 4

PUBLIC GROUNDWATER SYSTEMS IN SHENANDOAH COUNTY

System	Average Pumpage (GPD)
Battleground Trailer Park	8,500*
Blue Ridge Homes (Section 2)	9,000*
Blue Ridge Trailer Court	6,800*
Borden's Trailer Park	8,000*
Concord Mobile Homes	28,800
Edinburg (Town of)	338,530
Heishman's Trailer Park	9,000*
Holler Subdivision #2	16,000*
Lambert Mobile Home Park	86,400**
Massanutten Heights	3,600*
Massanutten View	5,000*
Mountain Run	16,000*
Mountain View	3,000*
Mountain Water Works	5,440
Mount Jackson (Town of)	169,254
New Market (Town of)	250,000
New Market Battlefield	516
Round Hill Trailer Park	2,500*
Ryman's Subdivision	4,000*
Stoney Creek Utilities	15,938
Sundance Mountain Subdivision	8,000*
Toms Brook-Maurertown Service Authority	46,871
Westbrook Subdivision	2,500*
TOTAL	1,043,649

*Normal production figures supplied by Virginia Department of Health
**Maximum production figures supplied by Virginia Department of Health

Source: Virginia Department of Health;
Virginia State Water Control Board - VRO

Industrial Systems. Industrial systems probably account for less than 1 MGD of groundwater withdrawal in Shenandoah County. Though some industrial systems are actually classified as public systems because one or more wells or springs may supply "sanitary" water, for the purposes of this report they are included as industrial systems. Major industrial users for which data are available are listed in Table 5.

TABLE 5

MAJOR INDUSTRIAL GROUNDWATER USERS IN SHENANDOAH COUNTY*

Industry	Average Pumpage (GPD)
Aileen (Edinburg)	8,000
Aileen (Woodstock)	3,000
Bowman Apple Products	20,000
Chemstone	25,797
Howell Metal Co.	86,400
Irvin Candy Co.	2,000
Johns-Manville	6,274
Rocco Farm Foods	495,000
Shenandoah Block	4,250
TOTAL	650,721

*Includes some systems actually classified "Public" by the Virginia Department of Health

Source: Virginia State Water Control Board - VRO

Statistics derived from data on file indicate that the average industrial well in this County is 378 feet deep and yields 97 gpm. Table 6 elaborates further on these figures. The majority of these wells have been developed in the carbonate formations; only two tap the Martinsburg Formation and none have been drilled in the Silurian/Devonian formations.

TABLE 6

INDUSTRIAL WELL STATISTICS, SHENANDOAH COUNTY*

	Depth (ft)	Yield (gpm)
Minimum	146	12
Maximum	700	400
Median	378	97

*Calculations based on records for 15 wells

Source: Virginia State Water Control Board - VRO

The four most prolific industrial wells (yields of 100 gpm or greater) have been developed in terrace and alluvial deposits overlying carbonate formations. Two wells (29 and 79) owned by Rocco Farm Foods in Columbia Furnace produce 393 and 400 gpm, respectively, from the Beekmantown Formation which is overlain by alluvial deposits bordering Stony Creek. Two wells (32 and 34) at the Bowman Apple Products Company in Mt. Jackson produce 100 and 220 gpm, respectively. These wells tap the Conococheague Formation which is recharged by overlying terrace deposits.

High-yield industrial wells generally have large-diameter casing. Wells with 20-inch casing are common, but usually the casing telescopes down to 12-, 10-, or 8-inch diameter at the bottom.

Domestic Wells. Domestic wells, including commercial and institutional wells, are numerous in Shenandoah County and are the most important source of water for the rural areas. Statistics indicate that 77 percent of the domestic wells on file yield 25 gpm or less. Only seven percent produce greater than 50 gpm. This does not necessarily indicate that higher yields are not available. Rather, it indicates that the majority of domestic needs are met with yields falling within the 25 gpm bracket, so further development is not necessary. This is further illustrated by the fact that the average domestic well in Shenandoah County is 241 feet deep (based on 238 wells) whereas the average industrial well is 378 feet deep (based on 15 wells).

Groundwater Development Problems

Invariably some problems do arise in Shenandoah County during the process of developing and maintaining a well system. Most of the problems are experienced in the carbonate rock areas and are directly related to solution channels.

Well Interference. Well interference in carbonate rock occurs when two or more wells tap interconnected solution channels. This causes no problem if the channel transmits a greater volume of water than all the wells can pump. However, if the volume is only enough for an adequate supply for one well, the result can be lowered levels in one or all wells. Lowered levels result in less available water, and occasionally levels drop below pump settings and cause wells to cease production altogether. Extended periods of dry weather tend to aggravate these conditions, since groundwater storage is likely to be reduced. Well interference can usually be avoided by not drilling adjacent to existing wells. Several cases of well interference have been reported in Shenandoah County, especially during periods of extended drought.

Sinkhole Collapse. A gradual, and sometimes sudden, settling of the land surface may result from over-development of the groundwater resources of an area. Accelerated solution activity in karst regions due to groundwater withdrawal often results in collapse of the land surface. Most often the collapse involves a relatively small area (less than 50 feet) and creates a sinkhole. Occasionally a subterranean stream may be revealed. Sinkhole collapse is usually the result of "underground erosion". A recent collapse in the north bound lane of Interstate 81 just south of the Edinburg exchange is a typical karst collapse phenonemon, though it is not known if the collapse was a direct result of groundwater withdrawal.

Mud Seams. A mud seam is a solution channel that is wholly or partially filled with mud. Mud seams are quite frequently encountered in drilling operations in Shenandoah County. Continuous pumping after tapping a mud seam will sometimes remove all the mud, though it may take several hours or even days to clear the water. In most cases, however, the seam must be cased off or the well abandoned.

CHAPTER V

GROUNDWATER QUALITY

Introduction

The quality of groundwater refers to its chemical, physical and biological characteristics. Groundwater contains dissolved mineral matter, has physical characteristics such as temperature, taste and odor, and may contain bacterial organisms. These factors are controlled in part by atmospheric gases, weathering and erosion of rock and soil, and the activities of man. Groundwater quality is highly influenced by the nature of the rock and soil with which it comes in contact since temperature, pressure and duration of contact determine the amount of dissolved minerals it contains.

Soil is nature's most efficient system of filtering water. Water infiltrating through thick soil cover stands an excellent chance of being purged of its harmful constituents or having them reduced to harmless concentrations. However, in areas where rock is exposed at the land surface, particularly in carbonate regions where the rock is prone to fracturing and solution activity, the water is introduced directly into the groundwater regime without the benefit of filtering. Lacking this cleansing action, it may carry chemical and biological pollutants which are capable of degrading the groundwater resources of an entire area.

More than 60 constituents and properties frequently are included in groundwater quality analyses. Many can be highly toxic and extreme health hazards, some are undesirable yet harmless unless in very unusual concentrations, and others are necessary for bodily functions and general good health. Constituents such as arsenic, cadmium, chromium, cyanide, mercury and lead are extremely toxic, while others such as copper, iron, manganese and zinc are generally only a nuisance but may be hazardous in large concentrations. Any groundwater supply intended for drinking purposes should be analyzed by the Virginia Department of Health. Table 7 is a summary of common quality parameters, their recommended limits, and hazards and benefits associated with them.

Groundwater Quality by Hydrogeologic Area

Two distinct groundwater quality trends emerge in Shenandoah County. Part of the County exhibits high hardness trends and normal iron concentrations, while the other sector has notably high iron concentrations but has minimal hardness. Plates 10 and 11 delineate general trends for hardness and iron, respectively, based mainly on geologic conditions and in part on available laboratory data. The County as a whole exhibits no major quality problems. Table 8 is a comparison of common quality parameters for the three hydrogeologic areas.

Central Valley Area

This area encompasses two hydrogeologic units: the Cambro-Ordovician carbonate formations and the Martinsburg Formation. While these two units are similar in many respects, significant quality differences do exist. The greatest variations occur for hardness, iron and manganese.

Groundwater in the Cambro-Ordovician carbonates is more highly mineralized than that found in the other hydrogeologic units. Total

TABLE 7

GROUNDWATER QUALITY PARAMETERS

Substance	Maximum Recommended Concentration (mg/l)*	Remarks
Bicarbonate	150	Seldom considered detrimental; lower amounts recommended for washing
Calcium	200	Seldom a health concern; may be a disadvantage in washing, laundry, bathing; encrustations on utensils
Chloride	**250 (Esthetics)	Taste is a major criterion; generally not harmful unless in very high concentrations, but may be injurious to sufferers of heart and kidney diseases; sea water is 19,000 mg/l
Fluoride	**1.4 (Health)	Presence of about 1.0 mg/l may be more beneficial than detrimental; below 0.8 mg/l may cause mottling of teeth; extreme doses (4 grams) may cause death
Hardness (as $CaCO_3$)	0-60 Soft 61-120 Mod. Hard 121-180 Hard Above 180 Very Hard	Hard waters have had no demonstrable harmful effects upon the health of consumers; major detrimental effect is economic--values above 100 mg/l become increasingly inconvenient; wastes soap and causes utensil encrustation
Iron	**0.3 (Esthetics)	Essential to nutrition and not detrimental to health unless in concentrations of several milligrams; main problems are bad taste, staining and discoloration of laundry and porcelain fixtures
Magnesium	150	Not a health hazard because taste becomes extremely unpleasant before toxic concentrations reached; may have laxative effect on new users
Manganese	**0.5 (Esthetics)	Essential to nutrition but may be toxic in high concentrations; taste becomes problem before toxic concentrations reached; undesirable because it causes bad taste, deposits on cooked food, stains and discolors laundry and plumbing fixtures
Nitrate	**10 as N, 45 as NO_3 (Appendix B listed as NO_3, Health Department as N) (Health)	May be extremely poisonous in high concentrations; may cause disease in infants ("blue baby"); irritates bladder and gastrointestinal tract, may cause diarrhea
pH	5.5-8.0	Indicates whether solution will act as an acid or base; water acquires "sour" taste below 4; high values favor corrosion control; efficiency of chlorination severely reduced when pH above 7
Potassium	1000-2000	May act as a laxative in excessive quantities
Sodium	100	May be harmful to sufferers of cardiac, circulatory, or kidney disease; concentrations as low as 200 mg/l may be injurious
Solids (Total Dissolved)	500	Not a health hazard above 500 mg/l, but may impart disagreeable taste, corrode pipes; general indicator of how highly water is mineralized
Specific Conductivity	1000	An indicator of the amount of dissolved solids in water; high concentrations can cause corrosion of iron and steel
Sulfate	**250 (Esthetics)	Above 250 mg/l may act as laxative on new users; may impart foul taste and odor

*Recommended concentrations based on current literature

**Actual limits established by the Virginia Department of Health; parentheses () indicate basis for limit

Source: McKee and Wolf (1963);
Virginia Department of Health

TABLE 8

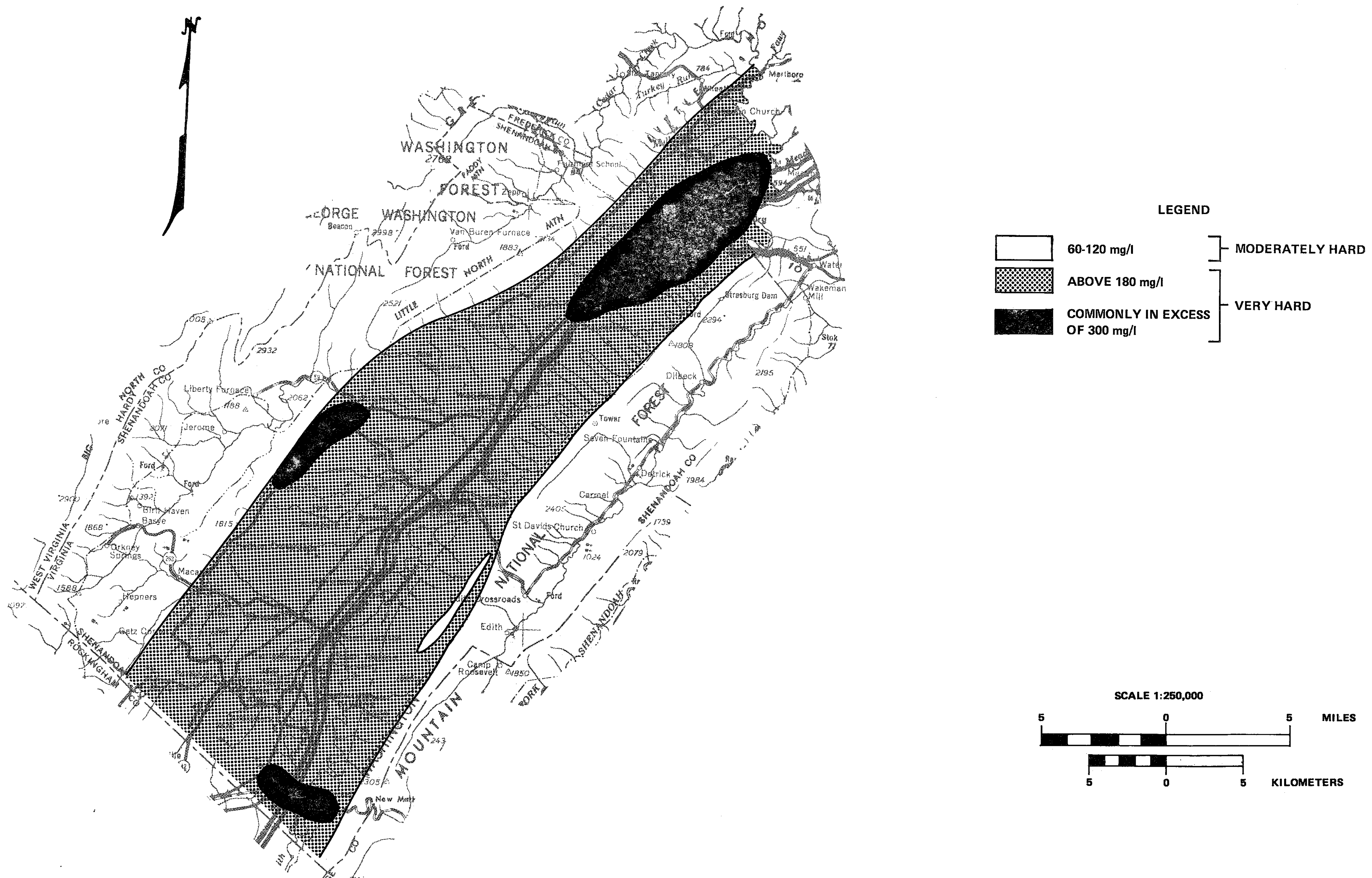
GROUNDWATER QUALITY PARAMETERS:
AVERAGE VALUES (MG/L) BY HYDROGEOLOGIC AREA, SHENANDOAH COUNTY*

Parameter	Central Valley Carbonates	Central Valley Martinsburg	Western Highlands and Massanutten Range
Calcium	(39)	(15)	(11)
Minimum	8.80	24.00	9.00
Maximum	175.00	196.00	56.00
Median	78.83	80.67	26.75
Hardness (Ca-Mg)	(38)	(15)	(11)
Minimum	131.00	112.00	32.00
Maximum	595.00	550.00	191.00
Median	309.08	255.53	103.91
Iron	(35)	(17)	(11)
Minimum	0.00	0.00	0.00
Maximum	4.00	1.80	6.20
Median	0.14	0.35	2.07
Magnesium	(39)	(15)	(11)
Minimum	2.30	3.50	2.40
Maximum	66.00	37.20	17.30
Median	28.16	14.57	10.22
Manganese	(29)	(14)	(10)
Minimum	0.00	0.00	0.00
Maximum	0.20	0.51	2.00
Median	0.05	0.16	0.38
Nitrate (as NO_3)	(35)	(15)	(9)
Minimum	0.00	0.00	0.00
Maximum	50.90	28.80	1.30
Median	15.34	6.15	0.33
pH	(40)	(17)	(11)
Minimum	7.00	6.50	6.30
Maximum	8.70	8.30	7.90
Median	7.52	7.28	7.24
Solids (Total Dissolved)	(38)	(16)	(11)
Minimum	172.00	169.00	61.00
Maximum	711.00	1186.00	440.00
Median	349.03	339.19	186.09

*Parentheses () indicate number of wells used in making calculations

Source: Virginia State Water Control Board - VRO

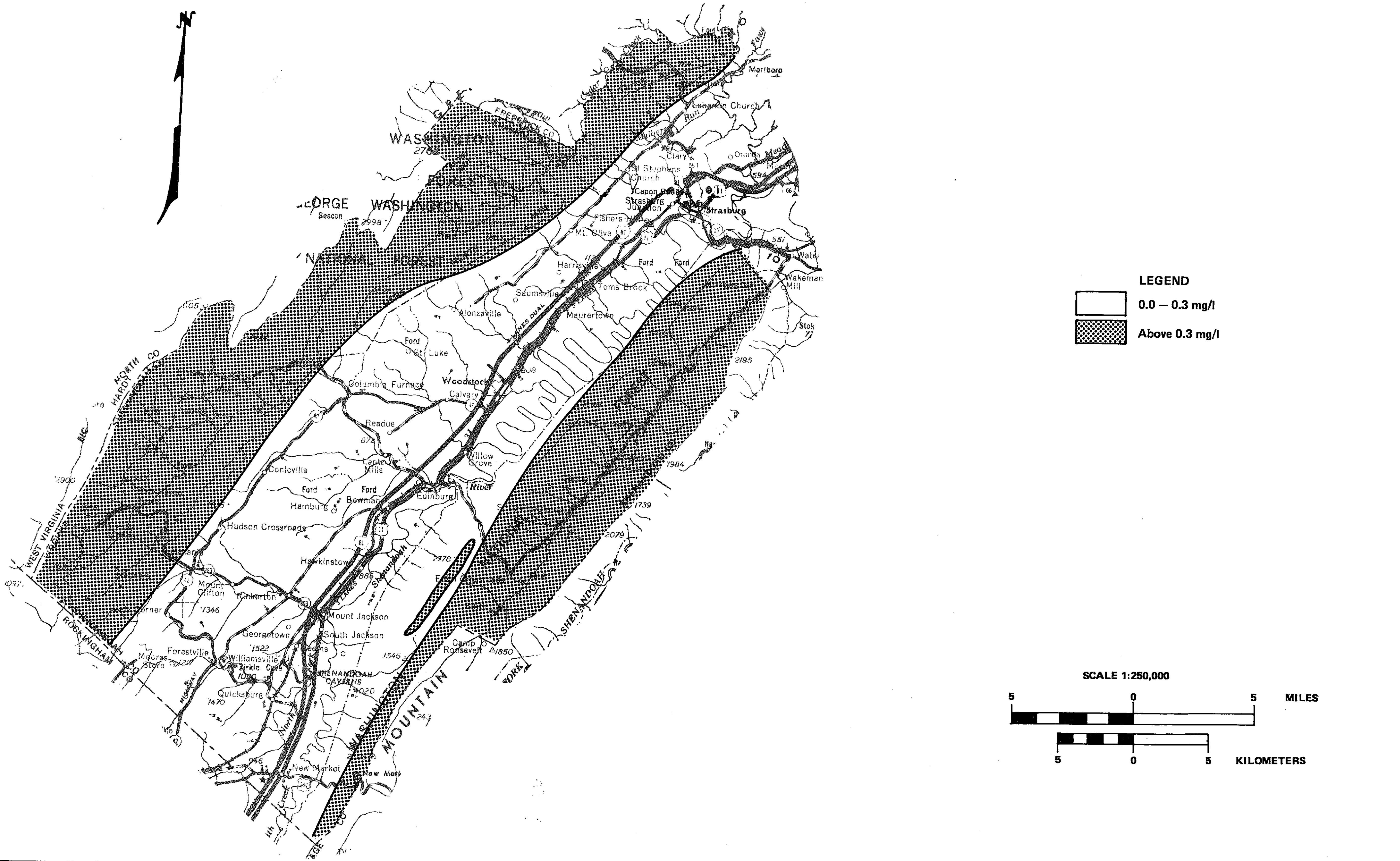
GROUNDWATER HARDNESS TRENDS IN SHENANDOAH COUNTY



Source: Virginia State Water Control Board — VRO

PLATE NO. 10

TRENDS OF IRON CONCENTRATION IN GROUNDWATER
SHENANDOAH COUNTY



Source: Virginia State Water Control Board – VRO

PLATE NO. 11

KEY WATER WELLS IN SHENANDOAH COUNTY

LEGEND

● WELL

WELL NUMBERS MAY BE CROSS-REFERENCED WITH APPENDICES B AND C.

SCALE 1:250,000

5 0 5 MILES

5 0 5 KILOMETERS

Source: Virginia State Water Control Board – VRO

PLATE NO. A-1

dissolved solids average around 350 milligrams/liter (mg/l), but some areas tend to exhibit unusually high concentrations. Well (57) southwest of Strasburg has the highest concentration reported in the carbonates at 711 mg/l, but concentrations greater than 500 mg/l have been detected at several locations along the major thoroughfares (U.S. Route 11 and State Route 42). Hardness averages above 300 mg/l; values in excess of 400 mg/l are prevalent in the Strasburg and Columbia Furnace areas. Manganese is unusually high in the northern section of Strasburg but is not considered a problem in any of the carbonate formations.

Iron, chloride and sulfate trends are well below accepted standards. The Toms Brook Highway Shop well (57) has a chloride value of 90 mg/l, twice as high as any other well in the County. This unusually high concentration has been attributed to the storage of highway de-icing salts at the installation.

The Martinsburg Formation exhibits quality characteristics similar to the carbonates with a few exceptions. Total mineral matter is nearly identical, but hardness is somewhat lower at approximately 255 mg/l; the water, however, is still considered very hard. The major differences are in iron and manganese, both being found in greater concentrations in the Martinsburg. Iron averages 0.35 mg/l, just above the 0.3 mg/l drinking water limit established by the Virginia Department of Health. Manganese averages in excess of 0.15 mg/l which is above the 0.05 mg/l limit imposed by the Health Department. The high iron and manganese concentrations do not appear to be isolated to any particular area.

Western Highlands and The Massanutten Range. The groundwater encountered in these hydrogeologic areas is generally of excellent quality with the exception of iron and manganese concentrations. Iron, on the average, has been measured in excess of 2 mg/l, far above the 0.3 mg/l limit established by the Virginia Department of Health. Concentrations as high as 6.2 mg/l in well (134) and 2.9 mg/l in well (156) have been detected approximately one mile west of Conicville; well (142) just south of Orkney Springs was recorded at 3.7 mg/l.

Manganese concentrations average nearly 0.4 mg/l, eight times the Virginia Department of Health drinking water limit of 0.05 mg/l. Wells (134) and (156) west of Conicville showed concentrations of 1.25 mg/l and 0.41 mg/l, respectively. Manganese of 0.44 mg/l was detected in well (112) two miles west of Columbia Furnace.

Iron in excess of 1.2 mg/l and manganese of 0.32 mg/l has been detected in wells (74) and (75) located in Fort Valley. At present this is the only quality data on file for the Massanutten Range in Shenandoah County.

Other groundwater quality parameter concentrations have proved to be far below those encountered in the Central Valley. Total dissolved solids are approximately one-half the concentration noted in the carbonates and the Martinsburg Formation, averaging approximately 185 mg/l, and hardness is comparatively low at approximately 100 mg/l. Sulfate values are surprisingly low (7 mg/l) for the rocks involved (principally shale), but only three analyses are available for this parameter.

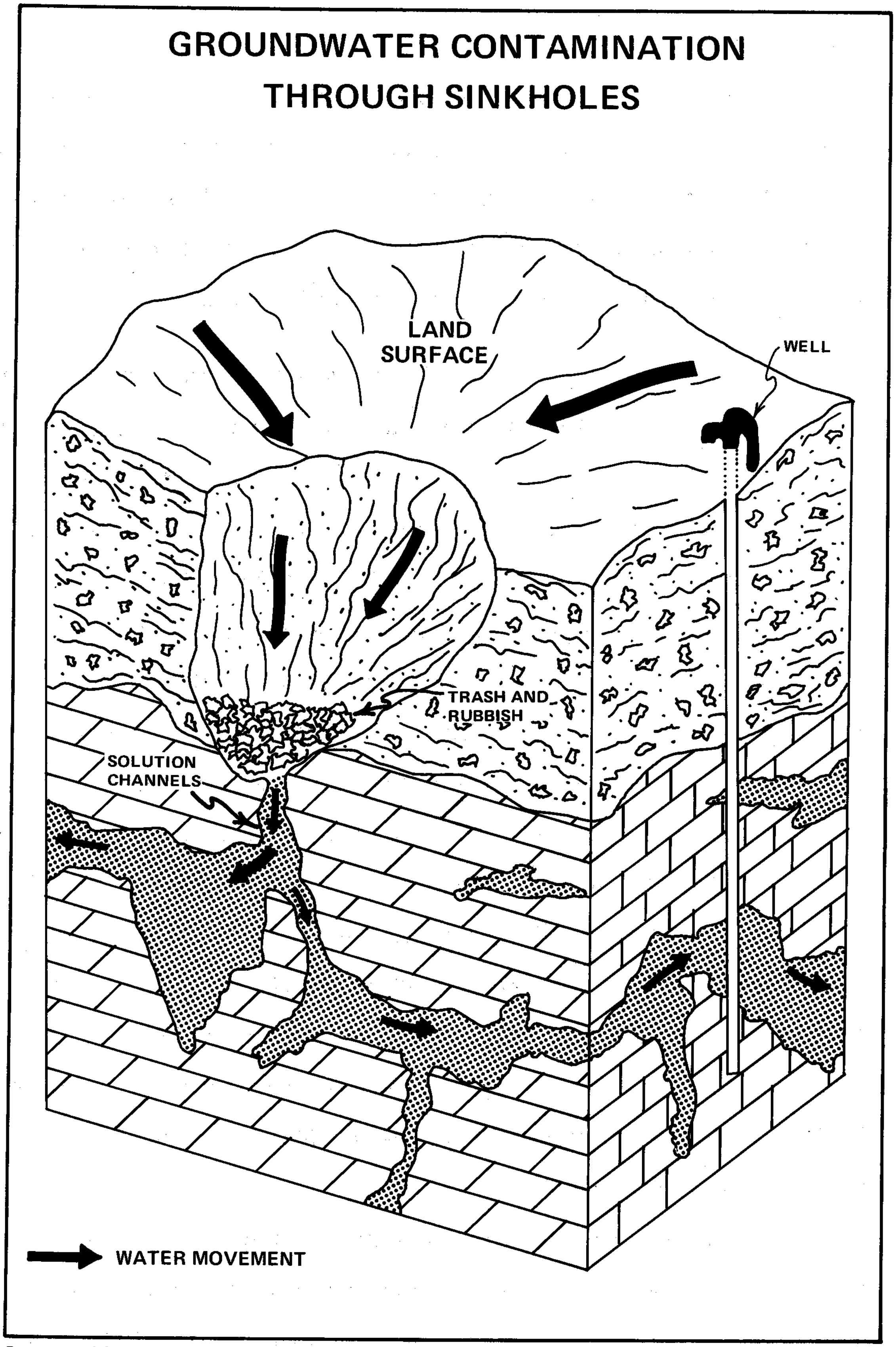
Groundwater Contamination

Groundwater contamination occurs when foreign matter of any nature enters the groundwater system and alters the natural quality. Pollution of a groundwater supply is far more serious than surface water pollution because there is no way to purify an aquifer system. All purification must be done on an individual basis.

Methods of Contamination. The most common groundwater contamination mechanisms in Shenandoah County involve the introduction of contaminants into solution channels via sinkholes and bedrock exposures at the surface. For this reason the areas underlain by carbonate bedrock are highly susceptible to contamination.

Sinkholes are a major threat because people tend to use these depressions in the land surface for the disposal of dead animals, trash and other wastes. Additionally, sinkholes are collection areas for surface runoff which may carry other pollutants. The absence of an adequate soil cover at the bottom of the sinkhole means simply that water passing through the overlying rubble will not be filtered of harmful constituents before it enters solution channels beneath the depression. Once the pollutants have entered the groundwater regime, they may spread in unpredictable patterns to areas being tapped as water sources by unsuspecting well owners. Plate 12 pictures a typical sinkhole situation showing the high potential for contamination.

Exposures of carbonate bedrock on the land surface and areas in which only a very thin soil cover overlies carbonate bedrock afford excellent opportunities for groundwater contamination. As



Source: Virginia State Water Control Board — VRO PLATE NO. 12

with sinkholes, the key factor is the lack of adequate soil cover to purge wastes from surface runoff.

Sources of Contamination. Though there have been no major areas of groundwater pollution identified in Shenandoah County, local contamination occurs occasionally. The most significant potential sources of groundwater contamination are septic tank drainfields; agricultural runoff from croplands, barnyards and feedlots; spills and leakage of petroleum and hazardous chemicals; and leakage from sanitary landfills and waste treatment facilities.

Septic tank systems are a common form of domestic sewage treatment in this County. If an inadequate soil cover houses the septic tank drainfield, pollutants will not be filtered out before they enter the groundwater. Nitrates and coliform bacteria are the most common contaminants from septic systems.

Agricultural runoff from croplands often causes nitrate contamination from fertilizers. In addition, pesticides and herbicides also may be negative factors. Barnyards and feedlots are also a common source of bacterial contamination.

Hydrocarbon contamination caused by spills and leakage of petroleum products has been reported in several areas of the County. Minute amounts of petroleum in groundwater may cause foul tastes and offensive odors. Occasionally the water returns to a normal state in a reasonable time if the source can be identified and eliminated. In many cases, however, it is impossible to determine the source of the contamination because petroleum products undergo drastic changes once they come in contact with rocks and soil.

Several incidents have occurred recently in Shenandoah County and are still under investigation. West of New Market, drainage pipes which apparently drain springs in the area have been found to be contaminated with some type of petroleum product, probably gasoline. The source is as yet unknown but is possibly one of several service stations in the immediate area. An incident in Edinburg involving a newly-drilled well at a local business establishment is possibly related to an old gasoline storage tank which has long since been removed from the ground. The tank at the time of removal was reported to be in a leaky state; gasoline which may have escaped from the tank likely has saturated the soil in the area and could be the source of the contamination.

Sanitary landfills and waste treatment facilities are potential sources of groundwater pollution. Industrial wastes often contain heavy metals which can be highly toxic in sufficient quantities. Landfills produce leachate, a "grossly polluted liquid characterized by high concentrations of dissolved chemicals, chemical and biological demand, and hardness" (Zaporozec, 1974). The key to pollution prevention is responsible management and operation of waste disposal facilities. Groundwater monitoring is an effective method of determining the presence and extent of contamination. Shenandoah County has exhibited no known groundwater pollution from any waste disposal sites, though most facilities have been in operation for many years.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The groundwater resources of Shenandoah County are an important water supply source. Approximately half of the County's population is supplied by groundwater. Present groundwater development is confined mainly to the Central Valley area with the majority of the development being in the carbonate units. The Martinsburg Formation is a reliable water-bearing unit but has been developed to a lesser extent. Maximum potential is possible from the alluvial and terrace deposits overlying the carbonate rocks and the Martinsburg Formation. Present groundwater development can probably be tripled without adverse effects as long as responsible management practices are observed.

Groundwater quality is generally very good. High hardness is common from the carbonates and the Martinsburg Formation, and excessive iron concentrations are commonly found in the Silurian and Devonian shale and sandstone units in the east and west. The Martinsburg shale is unusual in that iron concentrations rarely exceed 0.3 mg/l.

No major groundwater contamination problems exist in Shenandoah County. Isolated cases of local contamination are frequent and are usually the result of inadequate septic tank systems, agricultural runoff, or spills and leaks from petroleum facilities. Many potential pollution sources exist, and the areas underlain by carbonate formations are the most susceptible to contamination due to the presence of solution channels.

Recommendations

(1) The alluvial and terrace deposits extending from New Market to Edinburg along the North Fork of the Shenandoah River and to the west of Edinburg offer the greatest groundwater potential and can likely be developed to yield several million gallons per day if responsible management practices are observed.

(2) The Martinsburg Formation can be developed to a far greater extent and can be relied upon to produce good quality groundwater of moderate to good yields if well sites are selected to take maximum advantage of topography and geology.

(3) The carbonate formations underlying the Central Valley offer fair to good groundwater potential. However, these formations are more susceptible to groundwater contamination due to the presence of solution channels.

(4) Proper well development in the shale and sandstone formations along the West Virginia border, especially in the Basye area, will usually result in adequate supplies for domestic and small public and commercial uses.

(5) The shale and sandstone formations of the Massanutten Range should be considered only for small domestic uses.

(6) Hardness should be a consideration when developing supplies in the carbonate rocks and the Martinsburg Formation.

(7) Excessive iron concentrations should be considered when developing the Silurian and Devonian shale and sandstone formations.

(8) When the need to develop groundwater arises:

(a) consulting hydrogeologists, well drillers and representatives of this Agency are available for information and advice;

(b) the Virginia Department of Health must be contacted pursuant to developing a public supply well and should be contacted when developing a domestic drinking water supply;

(c) reports and samples required by the Groundwater Act of 1973 must be submitted to the State Water Control Board.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

APPENDIX A

KEY WATER WELLS IN SHENANDOAH COUNTY

The accompanying Shenandoah County map (Plate A-1) shows locations for approximately 150 of the more than 300 wells and springs indicated on the computer printout appearing in Appendix B. They are representative of the County as a whole as far as density is concerned. The numbers appearing next to each well/spring may be cross-referenced with the information contained in Appendices B and C.

APPENDIX B

SUMMARY OF WATER WELL DATA FOR SHENANDOAH COUNTY

The computer printout on the following pages lists basic data for wells and springs in Shenandoah County. This printout is updated frequently to include information from new Water Well Completion Reports which are constantly being submitted by water well drillers. The information under the heading "Aquifer" may be cross-referenced with Table 2, Chapter III. Locations for many of the wells may be found in Appendix A.

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT

SUMMARY OF WATER WELL DATA FOR SHENANDOAH COUNTY

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THE FOLLOWING LIST OF WELL DATA SUMMARIZES BASIC DATA OBTAINED FROM WATER WELL COMPLETION REPORTS WHICH ARE ON PERMANENT FILE IN THE OFFICES OF THE VIRGINIA STATE WATER CONTROL BOARD. ADDITIONAL INFORMATION FOR MANY OF THE WELLS IS AVAILABLE AND CAN BE OBTAINED BY CONTACTING THE APPROPRIATE REGIONAL OFFICE OR THE BUREAU OF WATER CONTROL MANAGEMENT AT THE AGENCY HEADQUARTERS IN RICHMOND.

************ EXPLANATION OF PARAMETERS ************

SWCB NO: STATE WATER CONTROL BOARD NUMBER - A SEQUENTIAL NUMBERING SYSTEM USED WITHIN A COUNTY; WHEN REFERRING TO A SPECIFIC WELL USE THIS NUMBER

OWNER AND/OR PLACE: IDENTIFIES ORIGINAL OR CURRENT WELL OWNER AND/OR LOCATION OF WELL

YEAR COMP: YEAR IN WHICH WELL CONSTRUCTION WAS COMPLETED

LOG: TYPE OF LOG ON FILE FOR WELL; D = DRILLERS, E = ELECTRIC, G = GEOLOGIC

ELEV: ELEVATION - MEASURED IN FEET ABOVE MEAN SEA LEVEL

TOTAL DEPTH: TOTAL DEPTH DRILLED, IN FEET, WITH RESPECT TO LAND SURFACE

BEDROCK: DEPTH TO BEDROCK, IN FEET, WITH RESPECT TO LAND SURFACE

CASING: MAXIMUM AND MINIMUM DIAMETER OF CASING, IN INCHES, USED IN WELL

DEVEL ZONE: DEVELOPED ZONE - INTERVALS, IN FEET, WHERE AQUIFERS TAPPED AND/OR SCREENED

AQUIFER: WATER-BEARING UNIT; ABBREVIATIONS USED INDICATE GEOLOGIC AGE OF UNIT AND ARE CONSISTENT WITH "GEOLOGIC MAP OF VIRGINIA" (DIVISION OF MINERAL RESOURCES - 1963)

STATIC LEVEL: DEPTH, IN FEET, TO WATER WITH RESPECT TO LAND SURFACE; MEASUREMENTS TAKEN WHEN WELL IS NOT PUMPED AND ARE GENERALLY THOSE RECORDED ON COMPLETION DATE

YIELD: REPORTED OR MEASURED PRODUCTION, IN GALLONS PER MINUTE

DRAWDOWN: DIFFERENCE, IN FEET, BETWEEN STATIC LEVEL AND PUMPING LEVEL; I.E., REPORTED OR MEASURED DROP, IN FEET, IN WATER LEVEL DUE TO PUMPING

SPEC CAPAC: SPECIFIC CAPACITY - YIELD PER UNIT OF DRAWDOWN EXPRESSED AS GALLONS PER MINUTE PER FOOT OF DRAWDOWN

HRS: HOURS - DURATION OF PUMP TEST, IN HOURS, FROM WHICH THE PRECEDING THREE ITEMS WERE DERIVED

USE: USE OF WATER OR WELL UNDER CONSIDERATION; DOM = DOMESTIC, PUB = PUBLIC, GOV = GOVERNMENT, IND = INDUSTRIAL, COM = COMMERCIAL, INS = INSTITUTIONAL, ABD = ABANDONED, DST = DESTROYED, IRR = IRRIGATION, RCH = ARTIFICIAL RECHARGE

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   W A T E R   C O N T R O L   M A N A G E M E N T

SUMMARY OF WATER WELL DATA FOR SHENANDOAH COUNTY

****

SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
2	HOLLY FARMS #3	76	D	1050	500	2	8		475	485	OMB	20	450			40	IND
4	LEONARD E CAMPBELL #2	65	D	1040	136	125	5		126	135	CCO	80	8	50	.16		DOM
6	BURTON CONWAY #1	63	D	1020	153	2	5		95	96	OMB	31	4	119	.03	2	DOM
7	OAK LEAF PARK #1	59	D		240	8	5					54	15	174	.08		PUB
8	TOWN OF EDINBURG #3	65		810	325		7				OST	35	205	20	10.25	8	PUB
10	VIRGINIA I GRIM #2	67	D		210	190	5		203	204			8				DOM
11	JONES #1	64	D	945	250	16	5				OB	47	1				DOM
12	SAMUEL M GARBER		D	1105	262	8	5				OMB	42	2			2	DOM
13	EVA S GUEST	60	D		60	5	5					18	15			2	DOM
14	EMMETT KNOWLES #1	67	D		145	85	5					30	7	100	.07		DOM
15	C W LONG #2	65	D	1010	421	21	5				OB		2				ABD
16	AL LACRAWS	62	D		500	65	5				DB	145	7				DOM
17	CALVIN WEATHERHOLTZ 2	65		1070	406	15	5				OMUU		1				ABD
19	FORT VALLEY ELEM #2	65	D	965	301	1	5		109	110	DLMU	50	2	10	.20		INS
20	RAYMOND L SINE #1	65	D	1150	123	21	5		120	121	CCO		8				DOM
21	AILEEN #2 (EDINBURG)	63	D	880	350	57	5		312	315	OMB	64	31	236	.13	6	IND
23	ELMER SHIRLEY	62			348	16	5					44	1	296		2	DOM
24	ERNEST E HEFF	62			152	12	5					43	4	87	.04	2	DOM
25	HEARTY OF VA INC #1	61	D	935	206	142					CCO						ABD
26	EDGE HILL FARM	70	D	920	145	85	7		88	145	CCO	87	40			7	COM
27	CONCORD MOBILE HOMES	70	D	950	252	114	6		219	220	CCO	152	35	15	2.33		PUB
28	ROCCO FARMS #1	69		940	250						OB	25	35	75	.46	12	ABD
29	ROCCO FARMS #2	70	D	940	456	30	20	10	105	125	OB	30	393	215	1.82	25	IND
									225	245							
30	POTOMAC PROJ OBS WELL				1124		6				DLMU						GOV
31	NORTHERN VA POULTRY	70	D	1020	325	80	6		290	291	OB	150	25				IND
32	BOWMAN APPLE PROD #4	41		885	493	44	6				CCO	40	100				IND
33	BOWMAN APPLE PROD #1	65	D	1180	511	17	7				OB		30			7	IND
34	BOWMAN APPLE PROD #2			890	172		8				CCO		220				IND
35	BOWMAN APPLE PROD #3		G	1285	700		6				OB		12				IND
36	DAN COOKE #1	71	D	840	605	108	6		161	162	OB	68	28	298	.09	48	DOM
37	BLUE RIDGE HOMES INC	71	D	890	650	40	6		102	106	OB	80	2				ABD
38	STONE SHOP REST #1	70	D	620	852	15	6		140	141	OMUU	50	10				COM
39	STONE SHOP REST #2	70	D	685	577	16	6		85	86	OMUU	150	6				ABD
40	STONE SHOP REST #3	70	D	685	325	16			285	286	OMUU	105	20				ABD
42	TOMS BR-MAURERTOWN #1	71	D		485	7	6		186	187	OB	110	4				ABD
43	R L RIFFE #1	71	D	720	688	38	6		160	161	OB	40	12				DOM
44	TOMS BR-MAURERTOWN #2	71	D						45	47	OB		48	66	.72	72	PUB
45	DAN COOKE #2	71	D	825	505	5	6		129	130	OB	9	10	134	.07	24	DOM
46	R L RIFFE #2	71	D	725	239	9	6		145	146	OB	40	30	107	.28	70	DOM
47	TOMS BR-MAURERTOWN #3	71	D		494	14	6										ABD
48	TOWN OF MT JACKSON #2	60	D	880	284	32	6		62	65	CCO	56	75	200	.37	28	PUB
49	TOWN OF NEW MARKET #1	25		1025	450						OMB		35				ABD
50	TOMS BR-MAURERTOWN #4	71	D	785	300	9	6		182	184	CCO	60	70			2	PUB

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT

SUMMARY OF WATER WELL DATA FOR SHENANDOAH COUNTY

SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
51	R L RIFFE #3	71	D	745	218	19	6		144	145	CCO		25				ABD
52	MOUNTAIN RUN INC #1	71	D	1705	710	21	6		99	100	OMB	160	20	540	.03	2	COM
53	LEISURE POINT #2	72	D	760	400	20	6		150	160	STC	50	40			10	COM
54	TOWN OF NEW MARKET #3	72	D	1020	420	5	12	7	158	160	OMUU	55	42	207	.20	16	ABD
55	BRYCE MOUNTAIN #3	72	D	1330	300	20	6		130	131	DB	115	90	180	.50	8	PUB
57	VA DEPT OF HIGHWAY #1	67		950	400	185	6				CCO	137	14			3	DOM
58	VA DEPT OF HIGHWAY #2	67		985	225		6				OB		15				DOM
59	VA DEPT OF HIGHWAY #3	67		930	375	37	6				CCO	101	40	142	.28	7	DOM
60	AILEEN #1 (EDINBURG)	62	D	900	450	61	6		124	148	OMB	115	30	325	.09		IND
62	STONEWALL SCHOOL	59		930	109		6				CCO	20	30	100	.30		INS
63	TOMS BROOK ELEM SCH			750			6				OB	50	10	150	.06		ABD
64	BOWMAN APPLE PROD #5			940	238		8				OB		100				IND
65	TOWN OF NEW MARKET #2	59		980	225	70	6				OB	42	160	25	6.40		PUB
67	HOLLY FARMS #1	66		945	208		5				CCO	93	12				IND
68	CHEMSTONE CORP #1	58		620	210		6				OB		7				IND
69	MOUNTAIN RUN INC #2	72	D	1195	450	15	6		89	90	OMB	95	15			2	COM
70	MOUNTAIN RUN INC #3	72	D	1110	100	15	6		35	50	OMB	20	100			1	COM
71	MOUNTAIN RUN INC #4	72	D	1180	190	35	6		135	150	OMB	70	183			72	COM
72	MOUNTAIN RUN INC #5	72	D	1205	265	38	6		69	75	OMB	50	275			72	COM
73	RICHARD MURRAY	72	D	970	165	61	6		135	136	CCO		20			3	COM
74	FORT VALLEY FOREST #1	76	D	1090	450	168	6		240	270	DLMU		30			1	COM
75	FORT VALLEY FOREST #2	73	D	1120	450	95	6		170	190	DLMU		25				COM
76	BRYCE MOUNTAIN #4	73	D	1630	725	35	6		260	261	DB	500	7				COM
77	BRYCE MOUNTAIN #5	73	D	1320	350	1	6		35	170	DB		25				COM
78	ROCCO FARMS #3	73	D	950	305	21	10	6	120	121	OB	27	60	113	.53	102	IND
79	ROCCO FARMS #4	73	D	950	480	18	10	8	450	452	OB	99	400	115	3.47	50	IND
80	BLUE RIDGE HOMES #3	73	D	1090	277	190	6		189	190	OMB		60			2	PUB
81	HOLLY FARMS #2	73	D	1050	450	10	6		185	186	OMB	20	200	275	.72	8	PUB
82	LEISURE POINT #1	72	D	930	750	20	6		150	175	STC	40	3	710		10	ABD
83	BRYCE MOUNTAIN #2	70	D	1450	415	1	6		115	120	DB	157	38	10	3.80	73	COM
84	BRYCE MOUNTAIN #1	70	D	1460	385	1	6		110	111	DB	160	38	14	2.71	73	COM
85	BRYCE MOUNTAIN #6	74	D	1330	350	1	6		140	141	DB	140	30			8	COM
									285	286							
86	ANDREW JERLICK	74	D	1160	250	14	6		125	126	DLMU	50	20			5	COM
87	JOHNS-MANVILLE #1	74	D	850	341	18	6		101	116	OB	84	20	102	.19	72	IND
									250	253							
88	MASSANUTTEN VIEW #1	74	D	955	205	60	6		120	140	CCO	40	50			4	PUB
89	BRYCE MOUNTAIN #7	74	D		300	1	6		112	113	DB	118	30				COM
90	EUGENE CRABILL	74	D	770	225	1	6		116	117	OMB		30				COM
91	ROBERT WEATHERHOLTZ	74	D	1185	349	170	6				OB	160	10			5	DOM
92	STONEWALL ELEM SCHOOL	75	D	935	250	35	6		235	236	CCO	125	60				INS
93	MELVIN CLEM	74	D	855	220	50	6		195	196	OB	65	20			3	DOM
94	TOMMY JONES	75		1030	355		6		94	95	OB	80	2	270		1	DOM
95	EVERETTE LARKIN	75	D	915	123	12	6				OB	62	20			2	DOM

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT

SUMMARY OF WATER WELL DATA FOR SHENANDOAH COUNTY

SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
96	MOUNTAIN WATER WORKS	30			100												DOM
97	TOWN OF MT JACKSON #1	53			620	18	8	6					46				PUB
98	NEW MARKET BATTLEFLD	66	D		395	1	5		390	395	OB	79	43	81	.53	24	PUB
99	BLUE RIDGE HOMES #1	72		1090	300		6				OMB	175	28				PUB
100	BLUE RIDGE HOMES #2	72		1080	425		6				OMB	150	18				PUB
101	AUBEY DELLINGER JR	71		900	240		6				OB	90	20				DOM
102	HEARTY OF VA INC #2	61		935	304		5				CCO	95	30	205	.14	5	IND
103	IRVIN INC	65		880	346		5				OB	91	30	150	.20	15	COM
104	DUKE LUTZ	74		890	525		6				OB	375	30				DOM
105	RUSSELL MANTZ #1	71		900	167		6				OB		30				ABD
106	RUSSELL MANTZ #2	71		905	275		6				OB	112	18				DOM
107	GEORGE G RABBIT	74		765	125						OMB	30	25				DOM
108	E M RITTENOUR	66		820	175						OB	55	10				DOM
109	M BORDEN	74		740	175						OB	30	35				DOM
110	HAROLD CLARK	75	D	680	105	1	6		90	100	OMB		20			2	DOM
111	LLOYD CLICK	75	D	765	165	1	6		90	91			15			2	DOM
112	LESTER FOLTZ	75	D	1020	70	20	6		40	90	DMA		22			4	DOM
113	RICHARD FOLTZ	75	D	1200	83	1	6		78	79	DMA		25			2	DOM
114	ERSTON HINES	75	D	680	205	10	6		196	197	OMUU		6			6	DOM
115	RICHARD HOTTLE	75	D	1095	205	30	6		180	200	CE		7			5	DOM
116	DONALD JORDAN	75	D	1010	130	20	6		120	121	CCO		20			2	DOM
117	GARY PHILLIPS	75	D	1530	279	30	6		270	271	DCK		5			3	DOM
118	MILLARD RITENOUR	74	D	965	164	122	6		158	160	OB		6			4	DOM
119	PAT ROBINSON	75	D	1040	110	20	6		100	101	DMA	30	12			3	DOM
120	LARRY RYMAN	75	D	908	145	40	6		138	140	OOE		20			6	DOM
121	GARY SHOWMAN	75		1010	70		6				OMB	32	12			2	DOM
122	FOREST HILLS SUB	75	D	1100	185	1	6		130	140	OMB	66	22			4	PUB
123	BRYCE MOUNTAIN #8	75	D		415	1	8		59	60	OB	62	22	255	.08	48	COM
124	BRYCE MOUNTAIN #7	75	D		500	1	6		492	493	OB		4	500		2	COM
127	HOWELL METAL CO #1	75	D	955	146	26			129	103	OB	15	60	75	.80	4	IND
128	L M NEWLAND CO #1	75	D	965	220	21	6		49	50	OMB	18	30	202	.14	1	PUB
129	L M NEWLAND CO #1	75	D	950	138	8	6		90	91	OMB	6	75	132	.56	1	PUB
130	BRH - ALONZAVILLE #1	75	D	1085	145	35	6		135	136	OST		35			5	PUB
131	BRH - ALONZAVILLE #2	75	D	1085	290	50	6		215	216	OST		60			5	PUB
132	WALTER CHRISMAN	75		1220	150		6				DMM		7				DOM
133	ELMER DELAWDER	75		1410	90		6		70	71	DR	70	20			1	DOM
134	STEVE DELLINGER	75	D	1405	125	10	6		120	121	DCH		25			2	DOM
135	CALVIN FADELY	75		1365	175		6				OMR	120	20	10	2.00	1	DOM
136	DARYL FUNKHOUSER	75	D	775	266	20	6		245	246	OB	35	4			2	DOM
137	H E KELLEY	75	D		165	100	6		160	161	OB	82	6			3	DOM
138	W L MULLIKIN	75	D	1230	246	60	6		235	236	OC	56	3			4	DOM
139	JERRY RYAN	75	D	1040	125	50	6		114	115	CCO	62	6			3	DOM
140	GEORGE SHIRKEY	75	D	1010	165	40	6		150	151	OMB	30	3			2	DOM
141	LLOYD SHIRKEY	75	D	1025	165	40	6		160	161	OMB	70	5			2	DOM

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT

SUMMARY OF WATER WELL DATA FOR SHENANDOAH COUNTY

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
142	LARRY SHOWALTER	75	D	1610	100	1	6	76	77	OB	43	7			2	DOM
143	ROBERT & LARRY SMITH	75	D	950	165	30	6	155	156	OB	68	12			3	DOM
144	C B SNYDER JR	75	D	965	80	50	6	75	76	CCO	30	8			4	DOM
145	GEORGE GOOD	75			125		6			OC	60	20	10	2.00	1	DOM
146	CHARLES CUSTER	75		1030	180		6			OB	30	1	150			DOM
147	WILLIAM C LAMBERT	75		970	220		6	140	141	OB	80	60	5	12.00	48	COM
148	TOWN OF MT JACKSON	75	D	895	625	31	8	50	52	CCO	72	100	82	1.21	48	PUB
149	WARREN L BARB	73		1450	139			90	92	DR		15				DOM
150	FLOYD BAKER	75	D	960	380	50	6	320	321	CCO	210	3			4	DOM
151	HARRY COOPER	75	D	920	450	1	6	440	441	CCO		8			4	DOM
152	BARBARA CROMWELL	75	D	995	63	1	6	61	62	OB	27	20			3	DOM
153	HENRY P HARRIS	75	D	1035	115	50	6	105	106	OB		20			3	DOM
154	RICHARD HOTTLE	75	D	1005	78	40	6	70	71	OMB	30	30			2	DOM
155	WAYNE VIAR	75	D	1230	205	30	6	200	201	CCO		4			2	DOM
156	KEITH ZIRKLE	75	D	1440	125	1	6	120	121	DHS	60	10			3	DOM
157	BRH - EDINBURG I #1	75	D		240	60	6	230	231	OB		30			8	PUB
158	RICHARD COFFMAN	75	D	124		1	6	114	115	OB	55	30			3	DOM
159	BRH - ALONZAVILLE II	75	D	1185	102	38	6	78	79	OB	35	40			4	PUB
160	AILEEN #1 (WOODSTOCK)									CCO						IND
161	IRAN LITTEN	75	D	1020	432	7	6	425	426	OC		40			3	DOM
162	CONWAY WATERS	75	D		103	10	6	100	101	OMB		25			2	DOM
163	LONNIE GALE	75	D		495	40	6			OC	45	3			4	DOM
164	CHARLES ANDREWS	73	D		114	15	6				30	5				DOM
165	DOUG BARRICK	73	D		103	85	6					15				DOM
166	WILLIS M BOWMAN	74			440	59	6	135	140	OC	85	40				DOM
167	BARNEY BURKE	74	D	1340	116	60	6			OMB		30				DOM
168	LEWIS BURKHOLDER JR.	71			96		6					3				DOM
169	DANIEL BURNER	74	D		137	15	6				70	8				DOM
170	THOMAS BURNER	72	D		166	8	6			CCO						DOM
171	HOMER CARDER	75	D		94	1	6			DR		60				DOM
172	J LEWIS CAMPBELL	42	D	1160	146	65	6			OMB	50	9				DOM
173	RALPH H COMBS	74	D		65	1	6					6				DOM
174	RAY CUSTER	71	D		300	5	6	292	300		108	40				DOM
175	WILMER DOVE	73	D		179	99	6					5				DOM
176	J L FARREN		D		112	12	6	110	113			12				DOM
177	EARL H FLEMING	65	D		135	90	6				100	2				DOM
178	ALGER E GALLADAY	73	D		443	15	6				100	4				DOM
179	DON GHEEN	73	D		103	45	6			CE	50	30				DOM
180	DON GHEEN	73	D		638	3	6			CCO	10	3				DOM
181	DON GHEEN	72	D		190	101	6			OB		15				DOM
182	RONALD GISEWHITE	73	D		208	15	6				3	2				DOM
183	LINDEN GOCHENOUR	75	D		156	18	6			OB		15				DOM
184	RAYMOND GOCHENOUR	74	D		302	48	6			OR	90	7				DOM
185	CHARLES GRIMM	75	D	945	258	15	6			OMB						DOM

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   W A T E R   C O N T R O L   M A N A G E M E N T

SUMMARY OF WATER WELL DATA FOR SHENANDOAH COUNTY

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
186	MOSE GRIMM		D		75	20	6				10	8				DOM
187	MRS LUVA KINGAN	74	D		90	1	6			OMB		50				DOM
188	SAMUEL B KOONTZ	72	D		248	30	6			OMB	30	6				DOM
189	MORTIOR LAFEVER	71			503		6			OB						DOM
190	CARROLL L LAM		D		165	15	6			OMB	20	20				DOM
191	RAYMOND LINDAMOOD	75		1250	102		6			CCO	30	1	65	.01		DOM
192	LARRY LITTEN	71	D	1065	96	18	6			OMB		6				DOM
193	BRH-MASSNTN VIEW #1	75	D	865	124	20		95	96	CCO	40	40			6	PUB
194	WALTER H MEARS	74	D	950	117	15	6			OMB	20	20				DOM
195	LOUISE MCCLANAHAN	75	D		220	95	6			OB	150	20				DOM
196	JAMES H MCDANIEL	71	D		180	15	6					2				DOM
198	WINFIELD MEADORS	71	D		218	36	6			OMB	48	3				DOM
199	ROBERT L MORGAN			1025	128	23	6			OMB		5				DOM
200	ERWIN MORSETON	74	D		255	45				OB	25	30				DOM
201	RICHARD MURRAY	72	D		165	61	6			CCO		20				DOM
202	L M NEWLAND	75	D		178	2	6	168	169			12				DOM
203	L M NEWLAND	71	D		48	42	6				8	10				DOM
204	CHARLES NICHOLSON	73	D		228	18	6					3				DOM
205	ANDREW O'NEILL	75	D		97	8	6			DR	10	12				DOM
206	DONNIE OREBAUGH				303		6					2				DOM
207	REASON OREBAUGH		D		94	26	6				20	6				DOM
208	GEORGE PATTON	74	D		265	12	6			CCO	80	30				DOM
209	DONALD PRYER	75	D		117	1	6			DR	30	10				DOM
210	NORMAN RACEY	73	D		248	35	6				15	2				DOM
211	PATRICIA RAYNES	73	D		232	4	6	220	221		15	100				DOM
212	NAPOLEON ROSE	74	D		157	10	6				15	6				DOM
213	ROY SEAL	73	D	740	85	15	6			OMB		25				DOM
214	D F SEIBERT	73	D		165	75	6					40				DOM
215	JACK SHOEMAKE	73	D		73	5	6			DR	6	20				DOM
216	GRANVILLE SIBERT	74	D	915	720	6	6	200	201	OC	30	150				DOM
217	LOUISE SMITH	74	D	1310	97	3	6			DB		30				DOM
218	CHARLES STREET	71	D		117	1	6			CCO	75	20				DOM
219	MELVIN STROOP	71	D	975	96	4	6			OMB		15				DOM
220	CALVIN SWARTZ	71	D		218	97	6					3				DOM
221	GEORGE TANHAM	74	D		218	22	6	120	135	OC		9				DOM
222	TREVA SAYLOR	71	D	1025	78	1	6			OMB	50	6				DOM
223	ALBERT TUSSING	74	D		157	55	6					8				DOM
224	DUARD WELLS	72	D		100	85	6			OB	80	20				DOM
225	GUY WINE JR		D		96	31	6				20	8				DOM
226	GUY WINE SR	73	D		65	12	5				22	9				DOM
227	RICHARD F HOTTLE	75	D		325	80	6	190	191	OOE	102	3			5	DOM
228	ED BURGER	75	D		328	10	6	325	326	CCO	73	4			12	DOM
229	GALEN LUDWIG	75	D	1245	155	10	6	150	155	CCO	70	10			3	DOM
230	OTTO L FULLER JR	76	D	900	430	20	6	429	430	OB		2			3	DOM

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   W A T E R   C O N T R O L   M A N A G E M E N T

SUMMARY OF WATER WELL DATA FOR SHENANDOAH COUNTY

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
231	MILDRED WHITTINGTON	75	D	990	100	1	6	90	91	DR	24	25			2	DOM
232	SIDNEY L DINGES	75	D	1080	225	12	6	194	195	OB	65	15			2	DOM
233	PAUL DELLINGER	76	D	1250	164	10	6	158	159	CCO		10			2	DOM
234	LAWRENCE MANDALA	76	D		205	100	6			OB		30			3	DOM
235	GARY WAKEMAN	76	D	1010	84	60	6	82	83	OMB	48	20			3	DOM
236	RICHARD F HOTTLE	75	D		90	30	6	85	86	CCO	49	12			2	DOM
237	ALETA MORGANTHEAU	75	D		246	10	6	240	241	CE		5			2	DOM
238	ROBERT TAYLOR	76	D	760	471	20	3	390	391	OMB		3			3	DOM
239	JOHN W WHETZEL	76	D		463	10	6	463	464	OOE		40			5	DOM
240	JOHN A PRICE	76	D		103	20	6	94	95	OC	58	12			2	DOM
241	FREDDIE GEORGE	75	D		245	50	6	200	201	CCO	140	15				DOM
242	DANIEL WOLVERTON	75	D		205	40	6	200	201	OMB		4			2	DOM
243	TOWN OF STRASBURG															DOM
244	A S WYMER		D		103						60	3				DOM
245	G L FRAVEL	75			745	120	6			OMB	12	25				DOM
246	JOHN COOPER	68		805	48		6			CCO		8				DOM
247	ETHEL HURLEY	66		670	320					CCO						DOM
248	ELVIN KIBLER	74		620	280		6			OMB						DOM
249	JOHN THOMPSON	76	D		58	52	6			OOE	21	12			4	DOM
250	BOBBY VANN	76	D		82	1	6	60	61	DEV	50	3			2	DOM
251	ELMER WAITE	76	D		140	5	6	134	135	OMB	51	6			2	DOM
252	ROBERT WALTZ	76	D		145	20	6	140	141	OOE		6			5	DOM
253	KENNETH WEATHERHOLTZ	46	D	1090	185	10	6	180	181	CCO		5			2	DOM
254	W WEATHERHOLTZ #1	76	D		185	5	6	120	171	DEV		7			2	DOM
255	W WEATHERHOLTZ #2	76	D	1380	120	30	6	90	91	DCH		12			2	DOM
256	JOE STINE	76	D		452	60	6	350	351	OMB	110	8			4	DOM
257	MERLYN LUDWIG	76	D	1235	280	1	6	275	276	CCO		6			4	DOM
258	BILL HOCKMAN	76	D		215	10	6	205	206	OB	67	15			3	DOM
259	TEDDY HELSLEY	76	D		307	30	6	300	301	OB	110	6			4	DOM
260	ROGER L GROSE	76	D	1250	215	15	6	210	215	CCO		4			2	DOM
261	ALVIN GEORGE	76	D		185	52	6	169	170	OB	90	10			4	DOM
262	CARL FLEMING JR	76	D		82	1	6	81	82	OMB	26	30			3	DOM
263	TONY DAVIS	76	D	1045	256	10	6	250	251	OOE		20	4	5.00		DOM
264	GALEN J DELLINGER	76	D	1150	120	40	6	119	120	CCO	51	20			5	DOM
265	RON CRABTREE	76	D		112	20	6	74	80	OMB	30	25			2	DOM
266	CHESTER COFFMAN	76	D		132	35	6		125	OOE	46	5			6	DOM
267	FRED W BORDEN	76	D		102	40	6	10	1010	OMB	28	6			2	DOM
268	BLUE RIDGE HOMES	76	D		155	25	6	14	5014	OB	96	12			3	DOM
269	BRH-ALONZAVILLE I #2	76	D		205	25	6	145	146	OOE		30			4	PUB
270	BRH - EDINBURG I #2	76	D		271	35	6	196	197	OB	92	30			4	PUB
271	BRH - VALLEY VIEW #1	76	D		165	25	6	160	161	OB	65	30			8	DOM
274	LINDA VARNEY	73		1025	375		6			OMB		6				DOM
275	JACK D COOPER	73		1010			6			OMB						DOM
276	J SHERMAN	75		915	126		6			OMB		20				DOM

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277	RALPH HOSAFLOK	68		905	80		6				OMB						DOM
278	BEVERLY POLK	70		985	175		6		165	166	OMB		13				DOM
279	COOPER BROS TIRE CO	76		880	262		6				OB		10				COM
280	SHENANDOAH TRACTOR			905	325		6				OB		32				COM
281	SHEN CO LANDFILL	73		910	335		6		315	316	OB		30				DOM
282	SHEN-VALLEY HOMES	73		1100	425	105	6		200	201	OMB	200	18				PUB
283	BERLIN RYMAN	76		890	177	59	6		165	166	OMB	40	15				DOM
284	JAMES V SORRELS	76		920	280	66	6		250	251	OB	75	10				DOM
285	WHOLESOME FOODS	76		925	440	114	10		435	436	CCO	80	20				IND
286	UNKNOWN	74		905	100		6		99	100	OB	10	100				DOM
287	TOM ESTEP	73		1000	300		6		285	286	OB	20	60				DOM
288	JIMMY ROSEN	75		970	275		6		260	261	OOE	40	7				DOM
289	QUICKSBURG POST OFFCE	76		980	125	42	6		95	96	CCO	60	30				DOM
290	RUSSELL LLOYD	76		1000	350	242	6		325	326	CCO	80	30				DOM
291	STEVE LONG	76		960	500	42	6		495	496	CCO	100	100				DOM
292	EDWARD HEBLERIN	75		915	325	50	6		300	325	CCO	125	60				COM
293	HARRY E LONG CORP #1	67		985	610		6		420	421	OB	86	8				COM
294	HARRY E LONG CORP #3	76		960	847	33	6		285	286	OB	83	6				ABD
295	H & C POULTRY	76		1120	152	63	6		145	146	OMB	20	25				COM
296	BRUCE M WILSON	76		1090	425	220	6		415	416	CCO	60	20				DOM
297	HELSLEY HOME BUILDERS	76		1180	325	183	6		250	251	OB		12				DOM
298	SAMMY HOTTLE	76		770	502	43	6		485	486	OMB	43	11				DOM
299	JACK COOPER SUB #1	76		1030	200	110	10	6	175	176	CCO	20	50				DOM
300	JACK COOPER SUB #2	76		1030	177	62	10	6	160	161	CCO	20	35				DOM
301	RAYMOND TISINGER	74		1040	925	2			465	466	OB	150	2				DOM
302	BILL STEDMAN	76		1000	600				455	456	OB	75	3				DOM
303	ALAN MOOMAW	75		1320	125	42			120	121	DCH	20	4				DOM
304	JOHN BOWDEN	76		1060	477	87			450	451	OB	40	100				DOM
305	GALEN DELLINGER #1	59		1035	125				98	99	OB	24	25				DOM
306	GALEN DELLINGER #2	64		1040	400				375	376	OB	110	25				DOM
307	JIM ROMICK	76		1190	252	41	6		200	201	OB	45	25				DOM
308	UNKNOWN	75		1520	145	42	6		140	141	DCH		50				DOM
309	EDGAR LAMMA JR	76		1720	102	53	10	6	99	100	DCH		80				DOM
310	HAZEL BOWMAN	74		660	100	22	6		40	95	OMB		120				DOM
311	H E KELLEY	75	D		402	42	6				CCO	395	60				DOM
312	EMIL RYNAR	76	D		325	178	6						8				DOM
313	JESSE STROSNIDER	76	D		377	74	6		350	351			20				DOM
314	ROBERT L BRIDGE	76	D		227	85	6		190	191			25				DOM
317	BRYCE MOUNTAIN	75			650						DB		1				ABD
318	WILLIS M BOWMAN #1	41		1040	404						OL		10				DOM
319	WILLIS M BOWMAN #2	50		1020	606						ON	60	3				DOM
320	WILLIS M BOWMAN #3	72		1020	905				59	85	ON	80	40				DOM
321	LAWRENCE HOTTLE	57			50		5				CCO	30	8			1	DOM
322	H G ALEXANDER	58	D		82		5				OB	68	8	4	2.00	1	DOM

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SUMMARY OF WATER WELL DATA FOR SHENANDOAH COUNTY

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
323	HARRY E LONG CORP #2	76		960	900						OB		12				DOM
324	RALPH REEDY			1080	575						CCO						DOM
325	JOHN DELLINGER	76	D		205		6						3			4	DOM
326	PAUL NESSELRODT	76	D		170		6				OB		25			2	DOM
327	BETTY RUSH	76	D		287		6				OMB		3			2	DOM
328	LEON F DELLINGER	76	D		305		6						2			2	DOM
329	HARRY COOPER	76	D		389		6				CCO		3			4	DOM
330	JOHNNY A RYMAN	76	D		430		6						5			2	DOM
331	CECIL BORDEN	76	D		102		6				OMB		15			3	DOM
332	ROBERT WILLIAMS	76	D		205		6				CCO		10			4	DOM
333	BETTY POOLE	76	D		123		6				CCO		6			3	DOM
334	JAMES B LAMBERT SR	76	D		41		6					3	15			2	DOM
335	ZANE COFFELT	76	D		256		6				CCO	72	7			3	DOM
336	CLIFFORD GEORGE	76	D		576		6				OB	60	6			3	DOM
337	JACK FANSLER	76	D		102		6						7			4	DOM
338	WAYNE KIPPS	76	D		246		6						4				DOM
339	WILLIAM SPITLER	76	D		300		6				CCO		15			4	DOM
340	LENNIE HIMELRIGHT JR	76	D		142		6				OB		12			3	DOM
341	JOHN SMOOT	76	D	945	594		6				CE		4			2	DOM
342	JACK F DODSON	76	D		205		6				OMB	87	15			2	DOM
343	STANLEY SHIPP	76	D	1000	123		6				OB		12			1	DOM
344	SHEN BLOCKS	65			120												PUB
345	HEARTY OF VA INC #2	61		935	160	145						95	30	205	.14	5	IND
346	RICHARD HOTTLE	76	D		205	10	6				OB		5			3	DOM
347	DONALD RYMAN	76			123		6				CCO		12			1	DOM
348	DENNIS SHOWMAN	76	D	1000	75		6				OOE		15			2	DOM
349	RALPH FRAVEL	76	D	760	143	50	6				OMB		6			2	DOM
350	CLYDE HENNING	76	D		325	20	6				DLMU		20			3	DOM
351	CLIFFORD GEORGE	76	D		435	100	6				OB					8	DOM
352	LESTER FOLTZ	76	D		102	20	6				DMA						DOM
353	KENNETH SHIRKEY	76	D		368	40	6						4			3	DOM
354	GARFIELD PHIPPS	76	D		287	120	6						8			4	DOM
355	WAYNE MARKLEY	76	D		102	20	6						10			2	DOM
356	BETTY MOOMAW	76	D		163	30	6				OB	33					DOM
357	TILDEN FEATHERS	76			380		6					60	3				DOM
358	ANNIE FLICK	76	D		118	65	6		65	118		58	20			3	DOM
359	BURGESS DELLINGER	76	D		150	47	6		46	150			20			3	DOM
360	RICHARD BOLES	76	D		184	20	6						4			3	DOM
361	RICHARD DOSS	76	D		190	80	6						5			4	DOM
362	HARRY COOPER	76	D		82	10	6						15			2	DOM
363	W M SULLIVAN	76	D		144	80	6						20			2	DOM
364	GEORGE BRILL	77			75		6					10	25				DOM
365	DONALD KEELER	77			100		6					60	12				DOM
366	CHARLES KENDALL	77			150		6					60	30				DOM

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   W A T E R   C O N T R O L   M A N A G E M E N T

SUMMARY OF WATER WELL DATA FOR SHENANDOAH COUNTY

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
367	EVERT MILLER	77			350		6				175	20				DOM
368	ALVIS SONNER	77			550		6				200	1				DOM
369	BETTY SHOWALTER	76			302		6				80	12				DOM
370	LAWRENCE BERRICK	76			400		6				60	4				DOM
371	RICHARD WETZEL	77			177		6				100	20				DOM
372	KENNETH JOHNSON	76	D		250	130	6					10				DOM
373	ELIZABETH FURN REC #2	66	G		1200	50	6	600	601		34	7			24	PUB
374	FOREST HILLS SUB	75		1100	185		6			OMB	66	22			4	PUB
375	RYMANS SUBDIVISION #1	74			720						182					PUB
376	RYMANS SUBDIVISION #2	74			635						165					PUB
377	BATTLEGROUND TRAILER															PUB
378	BORDENS TRAILER PK #1															PUB
379	BORDENS TRAILER PK #2															PUB
380	BORDENS TRAILER PK #3															PUB
381	HEISHMANS TRAILER #1															PUB
382	HEISHMANS TRAILER #2															PUB
383	HEISHMANS TRAILER #3															PUB
384	LAMBERT MOBILE HOMES				220		6					60				PUB
385	MASSANUTTEN HEIGHTS															PUB
386	MOUNTAIN VIEW #1															PUB
387	MOUNTAIN VIEW #2															PUB
388	ROUND HILL TRAILER PK															PUB
389	SUNDANCE MTN SUB #1															PUB
390	SUNDANCE MTN SUB #2															PUB
391	SUNDANCE MTN SUB #3															PUB
392	WESTBROOK SUBDIVISION															PUB
394	LAWRENCE V. HUFFMAN	76	D		287	18	6					5			3	DOM
395	BLUE RIDGE HOMES	77	D		246	20	6			CCO		4			2	PUB
396	HOWARD BROCK	77	D		184	21	6				30	10			3	DOM
397	H W DELLINGER & SONS	77	D		307	40	6					4			3	DOM
398	OTTO EVANS	77	D		120	30	6					30			5	DOM
399	FRED GEIGER	77	D		143	90	6					6			3	DOM
400	JOHN & DOROTHY GOTT	77	D		143		6				62	30			2	DOM
401	CALVIN HOSAFLOOK	77	D		190	80	6					30			4	DOM
402	J B HOWARD	77	D		202	40	6			TD	95	20			3	DOM
403	JAMES H KRANICH	77	D		225		6				70	15			3	DOM
404	WILLIAM H LOGAN	77	D		471	30	6				38	8			3	DOM
405	DONALD LYNCH	77	D		430		6					15			3	DOM
406	EDWARD L. MILLER	77	D		102	20	6			OB		10			2	DOM
407	E W ROBERTS	77	D		235	10	6				78	50			4	DOM
408	FRED WHETZEL	77	D		246	110	6				88	10			4	DOM

APPENDIX C

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR SHENANDOAH COUNTY

The computer printout on the following pages lists basic groundwater quality data available for certain of the wells and springs listed in the water well data summary (Appendix B). Locations for many of the wells may be found in Appendix A.

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   S U R V E I L L A N C E   A N D   F I E L D   S T U D I E S

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR SHENANDOAH COUNTY

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THE FOLLOWING LIST OF GROUNDWATER QUALITY DATA SUMMARIZES BASIC DATA OBTAINED FROM ANALYSES OF GROUNDWATER, COLLECTED FROM WELLS AND SPRINGS, WHICH ARE ON PERMANENT FILE IN THE OFFICES OF THE VIRGINIA STATE WATER CONTROL BOARD. ADDITIONAL GROUNDWATER QUALITY INFORMATION FOR MANY OF THESE WELLS AND SPRINGS IS AVAILABLE AND CAN BE OBTAINED BY CONTACTING THE APPROPRIATE REGIONAL OFFICE OR THE BUREAU OF SURVEILLANCE AND FIELD STUDIES AT THE AGENCY HEADQUARTERS IN RICHMOND.

************ EXPLANATION OF PARAMETERS ************

SWCB NO: STATE WATER CONTROL BOARD NUMBER - A SEQUENTIAL NUMBERING SYSTEM USED WITHIN A COUNTY; WHEN REFERRING TO A SPECIFIC WELL USE THIS NUMBER

OWNER AND/OR PLACE: IDENTIFIES ORIGINAL OR CURRENT WELL OWNER AND/OR LOCATION OF WELL.

DATE SAMP: DATE SAMPLED - MONTH AND YEAR IN WHICH WATER SAMPLE WAS COLLECTED.

PH: HYDROGEN ION CONCENTRATION - BASED ON A SCALE OF 1 THROUGH 14, WATER WITH A PH GREATER THAN 7.0 IS CONSIDERED TO BE BASIC OR ALKALINE; THE LARGER THE PH VALUE, THE MORE ALKALINE THE WATER. WATER WITH A PH LESS THAN 7.0 IS CONSIDERED TO BE ACIDIC; THE SMALLER THE PH VALUE, THE MORE ACIDIC THE WATER.

SPEC COND: SPECIFIC CONDUCTIVITY - AN INDICATOR OF THE RELATIVE AMOUNT OF DISSOLVED MINERALS IN WATER; HIGHER VALUES INDICATE GREATER AMOUNTS OF DISSOLVED MINERALS; UNIT OF MEASUREMENT IS MICROMHO

T-DIS SOLID: TOTAL DISSOLVED SOLIDS - INDICATES TOTAL AMOUNT OF DISSOLVED MINERALS IN WATER; UNIT OF MEASUREMENT IS MILLIGRAMS PER LITER

HARDNESS TOTAL: TOTAL HARDNESS - CAUSED BY THE PRESENCE OF CALCIUM, MAGNESIUM, IRON, ZINC , AND OTHER TRACE METALS. UNIT OF MEASURE IS MILLIGRAMS PER LITER.

HARDNESS CA,MG: CALCIUM-MAGNESIUM HARDNESS - INDICATES THAT PORTION OF TOTAL HARDNESS CAUSED BY CALCIUM AND MAGNESIUM, WHICH ARE GENERALLY RESPONSIBLE FOR ALMOST ALL HARDNESS IN WATER. UNIT OF MEASURE IS MILLIGRAMS PER LITER.

THE AMOUNT OF HARDNESS IN WATER WILL AFFECT THE ABILITY OF SOAP TO LATHER OR CLEANSE BECAUSE OF THE TENDENCY OF THE IONS CAUSING HARDNESS TO REACT WITH SOAP. THE HIGHER THE HARDNESS OF WATER, THE MORE DIFFICULT IT IS FOR SOAP TO LATHER.

NOTE: TOTAL HARDNESS IS GENERALLY DETERMINED BY CHEMICAL TITRATION WHEREAS CALCIUM-MAGNESIUM HARDNESS IS GENERALLY DETERMINED BY MATHEMATICAL CALCULATION FROM CHEMICALLY-DETERMINED VALUES FOR CALCIUM AND MAGNESIUM. BECAUSE OF THIS DIFFERENCE IN DETERMINATION, THE CALCIUM-MAGNESIUM HARDNESS VALUES FOR SOME ANALYSES WILL BE LARGER THAN THE TOTAL HARDNESS VALUE.

******** PARAMETERS LISTED BELOW ARE MEASURED IN MILLIGRAMS PER LITER ********

FE: IRON	MN: MANGANESE	CA: CALCIUM
MG: MAGNESIUM	NA: SODIUM	K: POTASSIUM
HCO3: BICARBONATE	SO4: SULFATE	CL: CHLORIDE
	NO3: NITRATE (AS NO3)	

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF SURVEILLANCE AND FIELD STUDIES

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR SHENANDOAH COUNTY

SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	HARDNESS CA,MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
4	LEONARD E CAMPBELL #2	10 75	7.3	260	174		154	0.10	0.01	43.0	11.5	1.0	1.7			6.0	15.5
6	BURTON CONWAY #1	7 74	7.5	720	565		445	0.20		155.0	14.2	20.5	1.1			46.0	3.1
20	RAYMOND L SINE	7 74	7.5	650	397		418	0.00		97.0	43.0	7.5	1.0			4.0	5.8
26	EDGE HILL FARM	11 75	7.3		239		131	0.00	0.00	49.0	2.3	1.0	1.6			7.0	22.2
27	CONCORD MOBILE HOMES	7 74	7.4	240	172		154	0.10		54.0	4.9	2.8	1.8			1.0	10.2
31	NORTHERN VA POULTRY	8 74	7.5	313	233		220	0.10		76.0	7.4	3.5	1.9			3.0	8.0
36	DAN COOKE #1	10 75	7.8	590	385		310	0.20	0.00	70.0	33.0	1.0	0.4			7.0	
38	STONE SHOP REST #1	12 75	7.7	700	503		461	0.00	0.40	129.0	34.0	14.0	0.6			12.0	0.4
57	VA DEPT OF HIGHWAY #1	8 74	7.1	920	711		499	0.20		175.0	15.2	18.3	1.8			90.0	12.8
58	VA DEPT OF HIGHWAY #2	7 74	7.5	230	192		194	0.20		70.0	4.8	3.5	0.8			1.0	7.1
59	VA DEPT OF HIGHWAY #3	8 74	7.4	350	257		205	0.10		63.0	11.7	4.8	2.0			18.0	16.8
60	AILEEN #1 (EDINBURG)	9 63	7.7				163	0.10	0.00	51.5	8.6	12.1		192	23.9	6.0	0.0
65	TOWN OF NEW MARKET #2		7.5			312	302	0.30	0.10	84.9	22.0	3.7	0.2		16.7	7.5	19.5
68	CHEMSTONE CORP	12 75	7.4	590	390		445	0.30	0.20	91.0	53.0	3.0	1.1			0.0	11.1
73	RICHARD MURRAY	8 74	7.4	251	177		163	0.10		58.0	4.6	2.3	1.8			2.0	7.5
83	BRYCE MOUNTAIN #2	10 73	7.8	168	177	84	80	1.04	0.68	17.6	9.0	11.5	0.7		9.8	2.0	0.0
84	BRYCE MOUNTAIN #1		7.9	218	168	104	103	0.60	0.00	26.3	9.3	14.0	0.7			3.0	0.0
91	ROBERT WEATHERHOLTZ	10 75	7.5	310	352		190	0.00	0.10	50.0	16.1	1.0	0.5			3.0	3.1
92	STONEWALL ELEM SCHOOL	2 76	7.1	240	185		141	0.10	0.00	31.0	15.5	3.0	0.8			12.0	17.7
93	MELVIN CLEM	6 75	7.2	650	476		595	0.00	0.01	130.0	66.0	6.1	1.4			12.0	13.7
94	TOMMY JONES	10 75	0.2	700	557		426	0.00	0.00	110.0	37.0	1.0	1.2			20.0	50.9
95	EVERETTE LARKIN	10 75	7.4	630	461		400	0.00	0.01	88.0	44.0	1.0	5.0			11.0	35.4
96	MOUNTAIN WATER WORKS	5 72	8.3			154	153	1.24	0.15	47.2	8.7	17.3	0.4			5.0	0.0

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF SURVEILLANCE AND FIELD STUDIES

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR SHENANDOAH COUNTY

SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	CA,MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
98	NEW MARKET BATTLEFIELD	10 72	8.7			281	280	0.00	0.00	8.8	62.9	1.1	1.1		15.0	2.6	2.2
102	HEARTY OF VA INC #2	10 75	7.4	320	222		198	0.00	0.00	64.0	9.4	1.0	0.9			3.0	3.5
103	IRVIN INC	11 75	7.2		322		310	0.00	0.00	65.0	36.0	1.0	0.3			7.0	14.6
104	DUKE LUTZ	12 75	7.8	690	484		478	0.00	0.00	93.0	60.0	18.0	3.8			0.0	26.6
106	RUSSELL MANTZ #2	12 75	8.1	390	250		264	0.00	0.10	55.0	31.0	9.0	1.2			0.0	4.9
107	G G RABBIT	12 75	7.9	840	657	460	449	0.00	0.20	148.0	19.4	40.0	0.8			21.0	28.8
108	E M RITTENOUR	10 75	7.5		471		426	0.20	0.01	92.0	48.0	1.0	0.9			5.0	
109	M BORDEN	10 75	7.6	580	460		350	0.10	0.00	76.0	39.0	1.0	1.1			8.0	
110	HAROLD CLARK	10 75	7.4	640	531		338	0.40	0.29	107.0	17.5	3.0	0.2			1.0	
112	LESTER FOLTZ	10 75	6.3	82	61		32	0.00	0.44	9.0	2.4	1.0	0.3			5.0	1.3
116	DONALD JORDAN	6 75	7.4	420	283		269	0.00	0.00	65.0	26.0	2.8	1.0			6.0	14.2
117	GARY PHILLIPS	11 75	7.8		152		122	0.00	0.00	29.0	12.2	10.0	0.0			3.0	0.0
120	LARRY RYMAN	6 76	7.2	320	198	172	203	0.00	0.00	72.0	5.9	5.0	1.3		4.1	4.0	7.1
121	GARY SHOWMAN	10 75	7.3	320	237		186	0.50	0.01	69.0	3.5	1.0	0.0			3.0	8.4
127	HOWELL METAL CO. #1	10 75	7.0	370	250		232	0.00	0.00	68.0	15.3	1.0	0.2			6.0	16.4
133	ELMER DELANDER	10 75	6.5	110	110		61	0.50	0.08	10.0	8.8	1.0	0.0			2.0	0.0
134	STEVE DELLINGER	12 75	7.5	170	148		71	6.20	1.25	12.0	10.2	12.0	0.9			6.0	0.0
136	DARYL FUNKHOUSER	10 75	7.7	540	433		344	0.30	0.04	112.0	15.8	1.0	3.6			8.0	
139	JERRY RYAN	10 75	7.4	470	347		295	0.10	0.00	94.0	14.9	1.0	2.7			10.0	26.6
140	GEORGE SHIRKEY	11 75	7.4		268		214	0.00	0.00	65.0	12.7	1.0	0.0			8.0	13.3
141	LLOYD SHIRKEY	11 75	7.2		183		149	0.30	0.01	50.0	6.0	1.0	0.0			4.0	5.3
142	LARRY SHOWALTER	10 75	7.3	310	440		191	3.70	0.20	56.0	12.7	1.0	1.1			2.0	0.0
143	ROBERT & LARRY SMITH	12 75	7.7	540	380		377	0.00	0.00	92.0	36.0	5.0	0.5			1.0	7.1

NOTE--ALL ZEROS (00.00) - ANALYSED. NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED. REFER TO ANALYSIS

VIRGINIA STATE WATER CONTROL BOARD

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SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR SHENANDOAH COUNTY

SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	CA,MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
144	C B SNYDER JR	10 75	7.4	500	344		331	4.00	0.03	67.0	40.0	1.0	0.5			3.0	2.2
149	WARREN L BARB	10 75	6.9	10	223		121	5.00	2.00	37.0	7.1	1.0	0.0			1.0	0.0
151	HARRY COOPER	12 75	8.0	600	399		384	0.10	0.10	85.0	42.0	4.0	1.8			1.0	0.0
152	BARBARA CROMWELL	10 75	7.3	380	253		246	0.20	0.01	80.0	11.3	1.0	0.9			2.0	4.0
153	HENRY P HARRIS	12 75	7.9	310	210		190	0.10	0.10	68.0	5.1	6.0	0.2			7.0	9.3
156	KEITH ZIRKLE	10 75	7.0	165	170		76	2.90	0.41	13.0	10.8	3.0	0.3			5.0	
167	BARNEY BURKE	10 76	6.5	280	169		112	0.20	0.51	24.0	12.9	13.0	0.4			3.0	0.0
185	CHARLES GRIMM	2 76	7.0	500	408		232	0.20	0.03	66.0	16.4	50.0	0.3			12.0	0.0
191	RAYMOND LINDAMOOD	12 75	7.7	640	465		411	0.10	0.10	86.0	48.0	11.0	1.4			14.0	23.0
192	LARRY LITTEN	1 76	7.2	630	389		327	1.80	0.07	114.0	10.4	6.0	0.5			13.0	1.3
194	WALTER MEARS	6 76	7.1	10	156	102	123	0.70	0.14	41.0	5.1	6.0	0.0		21.7	4.0	0.0
199	ROBERT L MORGAN	1 76	6.9	580	399		281	0.70	0.44	80.0	20.0	12.0	0.8			8.0	0.0
213	ROY SEAL	5 76	7.0	1150	983		550	0.30	0.13	196.0	15.0	47.0	0.9		400.5	39.0	0.0
216	GRANVILLE SIBERT	2 76	7.1	445	341		302	0.10	0.00	65.0	34.0	28.0	0.7			12.0	14.2
219	MELVIN STROOP	6 76	7.1	530	405	284	303	0.40	0.61	91.0	18.7	16.0	0.2		118.2	13.0	0.0
222	TREVA SAYLOR	1 76	7.3	540	354		257	0.20	0.19	73.0	18.3	12.0	0.8			13.0	0.9
230	OTTO L FULLER	5 76	7.0	680	463		417	0.10	0.01	103.0	39.0	12.0	1.7		497.8	18.0	7.5
235	GARY WAKEMAN	6 76	7.4	260	194	144	169	0.20	0.02	63.0	2.9	6.0	0.0		8.1	3.0	4.9
238	ROBERT TAYLOR	5 76	6.9	1300	1186		448	0.20	0.12	150.0	18.0	48.0	7.1		481.4	10.0	0.0
245	G L FRAVEL	5 76	7.0	750	1070		775	3.20	0.19	250.0	37.0	41.0	0.8		482.4	6.0	0.0
247	ETHEL HURLEY	5 76	7.0	690	517		345	0.10	0.02	109.0	18.0	8.0	6.0		67.9	1.0	0.0
274	LINDA VARNEY	6 76	7.3	300	206	164	197	0.00	0.00	73.0	3.7	7.0	0.1		8.4	3.0	4.0
276	J SHERMAN	6 76	7.2	500	351	252	319	0.00	0.01	118.0	6.1	8.0	0.0		21.9	120.0	5.8

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF SURVEILLANCE AND FIELD STUDIES

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR SHENANDOAH COUNTY

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SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	HARDNESS CA.MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
277	RALPH HOSAFLOK	6 76	7.0	330	226	210	221	0.00	0.00	86.0	1.8	5.0	0.0		2.9	2.0	3.1
278	BEVERLY POLK	6 76	7.3	310	212	178	195	0.00	0.00	72.0	3.8	9.0	0.0		3.9	5.0	5.3

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

GLOSSARY OF TERMS

ALLUVIUM: A general term for sediments deposited during recent geologic time by a stream or other body of water.

ANTICLINE: An upward fold in rock strata.

AQUICLUDE: A geologic formation, group of formations or part of a formation which is not permeable enough to furnish an appreciable supply for a well or spring.

AQUIFER: A geologic formation, group of formations or part of a formation capable of supplying water to wells and springs in usable quantities. An aquifer is unconfined (water table) or confined (artesian) depending on whether the groundwater level is at atmospheric pressure or greater than atmospheric pressure due to the presence of an overlying, confining geologic formation (aquiclude).

BEDDING PLANE: The diversion plane in sedimentary or stratified rocks which separates the individual layers, beds, or strata.

BEDROCK: Any solid rock exposed at the surface or overlain by unconsolidated materials.

CALCAREOUS: Containing calcium carbonate.

CARBONATE ROCK: A rock consisting chiefly of carbonate minerals such as limestone and dolomite.

CATCHMENT: The area comprising the actual water intake area for aquifer recharge and all areas that contribute surface water to the intake area.

CLASTIC: Consisting of fragments of rocks or of organic structures that have been transported mechanically to a place of deposition. Sandstone and shale are the most common clastics.

COLLUVIUM: Loose soil material or rock fragments deposited by the action of gravity, usually at the base of a slope or cliff.

DIP: The angle at which a rock bed is inclined from the horizontal.

DRAWDOWN: The measured difference between static level and pumping level in a well; the drop in the water level due to pumping.

EVAPOTRANSPIRATION: A term embracing that portion of the precipitation returned to the air through direct evaporation or by transpiration of vegetation, no attempt being made to distinguish the two.

FAULT: A fracture or fracture zone along which there has been movement of two rock masses relative to one another parallel to the fracture. The movement may be a few inches or many miles, horizontal or vertical.

FLOOD PLAIN: The strip of relatively smooth land adjacent to a river channel and built of alluvium carried by the river during floods. The flood plain is covered by water when the river is in flood.

FOLD: A curve or bend in rock strata.

FORMATION: A unit of geologic mapping consisting of a large stratum of some one kind of rock.

FRACTURE: Breaks in rocks due to intense folding or faulting.

GPD: Gallons per day.

GROUNDWATER: Water below the water table; water in the zone of saturation.

HYDROLOGY: The science that relates to the water of the earth.

IGNEOUS: Rocks or minerals that solidified from molten rock (magma).

IMPERMEABLE: Having a texture which does not allow perceptible movement of water through rock.

INTRUSIVE:	Refers to igneous rocks which have penetrated into or between older rocks while molten but have solidified before reaching the surface.
JOINT:	A fracture in rock along which no appreciable movement has occurred. Joints are generally perpendicular to bedding planes.
KARST TOPOGRAPHY:	Topography characterized by sinking streams, sinkholes, caves and similar features indicative of underground drainage developed through the solution of bedrock.
LITHOLOGY:	The composition and structure of rock.
METAMORPHIC:	Refers to any rocks derived from pre-existing rocks in response to pronounced changes of temperature, pressure and chemical environment.
MGD:	Million gallons per day.
PERCOLATION:	Movement of water through the interstices of rocks or soils except movement through large openings such as solution channels.
PERMEABILITY:	The ability of a rock, sediment or soil to transmit water.
POROSITY:	The property of a rock, soil, or other material of containing spaces or voids.
PUBLIC SUPPLY:	As defined by the Virginia Department of Health, a water system serving more than 25 individuals or more than 15 residential connections.
PUMPING LEVEL:	Depth to water in a well when the well is being pumped.
RECHARGE:	The addition of water to an aquifer by natural infiltration or artificial means.
RUNOFF:	That part of precipitation that appears in surface streams. Groundwater recharge is that part of runoff which has existed as groundwater since its last precipitation.
SEDIMENT:	Material borne and deposited by water.
SEDIMENTARY:	Refers to rocks formed from the consolidation of layered sediments that have accumulated in water.

SINKHOLE: A funnel-shaped depression in the land surface, usually in limestone regions, developed by the dissolving action of water and connected with solution channels underlying the depression.

SOLUTION CHANNEL: Joints or fractures in carbonate rocks which have been enlarged by the dissolving action of water and which are capable of transmitting large quantities of water.

STATIC LEVEL: Depth to water in a well when the well is not being pumped.

SYNCLINE: A downward fold in rock strata.

TERRACE: A level or gently inclined surface bordering a stream which represents a former level of the stream. Terraces are composed of alluvium produced by renewed downcutting of the flood plain or valley floor by the stream.

UNCONSOLIDATED: A sediment that is loosely arranged or unstratified, or whose particles are not cemented together.

WATER TABLE: The upper surface of the zone of rock or soil saturated with groundwater.

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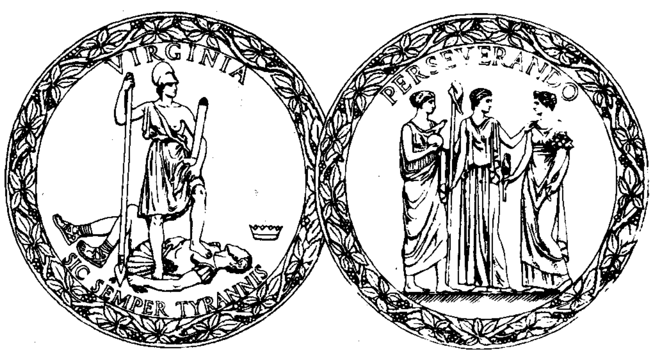
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